Draft Final

NASA-specific Sitewide Groundwater Quality Sampling and Analysis Plan Santa Susana Field Laboratory Ventura County, California

Prepared for

National Aeronautics and Space Administration

February 2018

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Acronyms and Abbreviations

µg/L	microgram(s) per liter
ABSP	Alfa-Bravo Skim Pond
AIG	Area of Impacted Groundwater
AP	Ash Pile
AST	aboveground storage tank
B204	Building 204
Boeing	The Boeing Company
CDFF	Coca/Delta Fuel Farm
CFGW	Chatsworth Formation Groundwater
cm/sec	centimeter(s) per second
CMI	corrective measures implementation
CMS	corrective measures study
COC	chemical of concern
DCE	dichloroethene
DOE	U.S. Department of Energy
DTSC	California Department of Toxic Substances Control
ELV	Expendable Launch Vehicle
EPA	U.S. Environmental Protection Agency
FSP	Field Sampling Plan
ft^2/day	square foot (feet) per day
GWQSAP	Groundwater Quality Sampling and Analysis Plan
GSL	groundwater screening level
HASP	health and safety plan
HSC	Health and Safety Code
HSU	hydrostratigraphic unit
HWSA	Hazardous Waste Storage Area
ID	identification number
LOX	liquid oxygen
MDL	method detection limit
NASA	National Aeronautics and Space Administration
NDMA	n-nitrosodimethylamine
NSGW	near-surface groundwater
PCB	polychlorinated biphenyl

PCP	Post-Closure Permit
PLF	Propellant Load Facility
QA	quality assurance
QC	quality control
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RP	Responsible Party
SPA	Storable Propellant Area
SSFL	Santa Susana Field Laboratory
STP	Sewage Treatment Plant
SWMU	solid waste management unit
TCE	trichloroethene
TCP	trichloropropane
UST	underground storage tank
VC	vinyl chloride
VOC	volatile organic compound

SECTION 1

Introduction

This National Aeronautics and Space Administration (NASA)-specific Sitewide Groundwater Quality Sampling and Analysis Plan (NASA-specific Sitewide GWQSAP) presents the proposed groundwater monitoring network, monitoring parameters, sampling frequency, and sampling methods for the NASA Areas of Impacted Groundwater (AIGs). This document is modified from the *Site-Wide Water Quality Sampling and Analysis Plan, Santa Susana Field Laboratory, Ventura County, California* (Haley & Aldrich, 2010a). The NASA AIG site conceptual models described in the NASA Groundwater RFI Report (2017a) were used to identify sampling locations in this NASA-specific Sitewide GWQSAP.

Sitewide groundwater monitoring is required at Santa Susana Field Laboratory (SSFL) in Ventura County, California to fulfill the requirements of the Consent Order for Corrective Action (Docket Number P3-07/08-003; DTSC, 2007). This sitewide monitoring is conducted by the three Responsible Parties (RPs) at SSFL: NASA, The Boeing Company (Boeing), and U.S. Department of Energy (DOE). This document provides the NASA portion of the sitewide groundwater sampling at SSFL and is specific to the four AIGs associated with NASA-administered parts of Area I and Area II at SSFL. The objective of the NASA-specific sitewide groundwater sampling is to provide information to support NASA's corrective measures study (CMS) and corrective measures implementation (CMI) by continuing to collect groundwater data associated with the AIG source areas and plumes and to support plume stability evaluations. Because the focus of the sitewide groundwater sampling in the NASA-administered areas has changed due to the updated understanding of site conditions presented in the NASA *Groundwater Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Report* (NASA Groundwater RFI Report) (NASA, 2017a), a revised NASA-specific sitewide groundwater monitoring program is warranted.

The SSFL sitewide groundwater monitoring program is separate from, and in addition to, the Regulated Unit monitoring program performed for Post-Closure Permit (PCP) Number PC-94/95-3-03 (DTSC, 2013). A Hazardous Waste PCP Renewal Application is in progress and will be submitted by NASA for formal California Department of Toxic Substances Control (DTSC) review and approval at DTSC's request. DTSC requested that the application be put on hold due to the recent changes to Health and Safety Code (HSC) Section 25247. According to HSC 25247, DTSC will adopt new regulations for post-closure plan requirements by January 1, 2018. Therefore, the existing PCP required monitoring, specified in *Regulated Unit Water Quality Sampling and Analysis Plan, Area II, Post-Closure Permit PC-94/95-03-03, Santa Susana Field Laboratory, Ventura County, California* (Haley & Aldrich, 2010b), is still in place at the time of the submittal of this NASA-specific Sitewide GWQSAP. This NASA-specific Sitewide GWQSAP is a standalone document and does not address the PCP monitoring program sampling. Changes to the PCP monitoring program will be laid out in a Demonstration Report and reflected in a DTSC permit change or order. To minimize field sampling cost and effort for these two programs, sampling duplication (assuming that sampling data from a location can be used for both programs) will be avoided.

1.1 Facility History and Description

SSFL is located approximately 29 miles northwest of downtown Los Angeles, California, in the southeast corner of Ventura County. SSFL was established in 1947 and occupies approximately 2,850 acres of hilly terrain, with approximately 1,100 feet of topographic relief near the crest of the Simi Hills. Prior to development, the land at SSFL was used for ranching. The majority of SSFL was acquired with the purchase of the Silvernale property in 1954, and development of the western portion of SSFL began soon after.

The site is divided into four administrative areas (Areas I, II, III, and IV) and includes undeveloped land both to the north and south. Most of Area I and all of Areas III and IV are owned by Boeing. A portion of Area IV is leased to DOE. Area II, a portion of Area I (associated with the former liquid oxygen [LOX] Plant) is owned by

the federal government and administered by NASA. The northern and southern undeveloped lands of SSFL were not used for industrial activities and are owned by Boeing (MWH, 2009).

The primary site activities at SSFL have included research, development, and testing of liquid-fueled rocket engines and associated components such as pumps and valves (SAIC, 1994). Test stands were constructed in the NASA-administered portions of SSFL at the Alfa Area, Bravo Area, Coca Area, and Delta Area between 1954 and 1957. Engine testing at the test stands occurred from the mid-1950s through 2006, with most testing taking place between the 1950s and the 1970s (NASA, 2014a). Environmental investigations have shown that the groundwater beneath SSFL has been impacted by past releases from operational activities, with trichloroethene (TCE) being the chemical detected at the highest concentration and with the greatest frequency.

NASA is responsible for a portion of Area I (NASA Area I) and Area II (NASA Area II) at SSFL, as shown on Figure 1-1. The four NASA AIGs (former LOX Plant AIG, Building 204/Expendable Launch Vehicle [B204/ELV] AIG, Alfa/Bravo AIG, and Coca/Delta AIG) are associated with these SSFL areas. Additional details regarding the background and operational history of the four AIGs can be found in the respective AIG-specific data evaluation report appendixes to the NASA Groundwater RFI Report (Appendixes A through D; NASA, 2017a).

Wastewater from the testing of rocket engines and engine components was contained in nine closed surface impoundments in Areas I, II, and III. A closure process for the nine closed surface impoundments was initiated in 1985 and completed in 1995 when Boeing and NASA submitted a notification of closure. In May 1995, two PCPs were issued for the site:

- Hazardous Waste Permit Number PC-94/95-3-02 (U.S. Environmental Protection Agency [EPA] identification number [ID] CAD093365435) for Areas I and Ill was issued to Boeing as owner and operator and successor in interest to the original permit issued to Rockwell International Corporation - Rocketdyne Division.
- Hazardous Waste Permit Number PC-94/95-3-03 (EPA ID Number CAD1800090010) for Area II was issued to NASA as owner and Boeing as operator.

Post-closure care of the four former surface impoundments administered by NASA in Area II is being conducted as required by PCP Permit PC-94/95-3-03. The former surface impoundments are Storable Propellant Area (SPA) impoundment 1 (SPA-1), SPA-2, Alfa-Bravo Skim Pond (ABSP), and Delta Skim Pond. One of the requirements in the PCP is groundwater monitoring of these former surface impoundments. Specific wells to be sampled, chemical analytes, and sampling periods are required by the PCP Sampling Plan. The PCP Sampling Plan was approved as part of the original 1995 Part B PCP and was revised in October 2013. A revised Area II Post-Closure WQSAP was prepared as part of the PCP Renewal Application, which is currently on hold pending DTSC adoption of new post-closure plan requirements. A Demonstration Report was generated to support the revised Sampling and Analysis Plan in the PCP Renewal Application. DTSC reviewed a preliminary draft of the Demonstration Report and did not have any comments. It is expected that the proposed post-closure groundwater sampling program in the Demonstration Report will be accepted under a new permit or order.

In addition to the former surface impoundments, 135 solid waste management units (SWMUs) and Areas of Concern at SSFL have been identified where chemicals of potential concern were or may have been released into the environment (MWH, 2009).

In 1992 DTSC issued a Stipulated Enforcement Order to impose RCRA Corrective Action requirements at SSFL; an additional Consent Order for Corrective Action was issued in 2007. A Site-Wide Groundwater Remedial Investigation Report (MWH, 2009) was submitted to DTSC in 2009. Substantial DTSC comments were received on the document which necessitated additional groundwater investigation field work. Revised draft RP-specific groundwater RFI documents that incorporate the additional investigation work have been submitted to DTSC and the RFI-related field work is considered complete. Additional monitoring

work under this NASA-specific Sitewide GWQSAP will support the CMS, CMI, remedial actions, and long-term plume stability monitoring work.

1.2 NASA AIGs

Figure 1-1 shows the NASA-administered areas of SSFL. NASA designated four AIGs within its property at SSFL. These AIGs include the following (NASA, 2017a):

1. The former LOX Plant AIG is located in NASA Area I. A LOX Plant operated in this area between 1955 and 1971 and provided LOX to each of the six large-engine test areas at SSFL. The AIG previously included several buildings, a potential septic tank and leach field (unconfirmed), debris points, the Northern Drainage, and two SWMUs (the waste oil sump and clarifier and the Asbestos and Drum Disposal Area). All the aboveground structures have been removed from the former LOX Plant area. TCE was used to clean LOX tanks and pipelines. Other potential chemicals used in the former LOX Plant AIG include waste oil, waste fuels, sodium hydroxide, and refrigerants (Freon and ammonia).
2. The B204/ELV AIG is located in the northern portion of Area II. The B204/ELV AIG includes the Building 204 Area, ELV, and the Ash Pile (AP)/Sewage Treatment Plant (STP).
    a. The Building 204 Area extends into Boeing's Area III, DOE's Area IV, and Boeing's undeveloped area to the north. It operated as a Plant Services Area and Maintenance Area for SSFL. It included several buildings, underground storage tanks (USTs), aboveground storage tanks (ASTs), a metal cutting equipment area, pole-mounted transformers, and the Western Debris Area. Potential chemicals used at the Building 204 Area include solvents, waste oil, fuels, metals, polychlorinated biphenyls (PCBs), and dioxins.
    b. The ELV is east of the Building 204 Area and extends into Boeing's undeveloped area to the north. It included two SWMUs (ELV Final Assembly Building 2206 where rocket engine components were tested and PCB Storage Facility Building 2231) and two Areas of Concern (Building 2206 Diesel UST and the Building 2207 UST). It also includes the ELV Catchment Pond where waste water may have drained. Most of the aboveground structures have been removed from the ELV. Potential chemicals used at the ELV include solvents, isopropyl alcohol, oils, fuels, metals, PCBs, dioxins, and furans.
    c. The AP/STP is located south of the ELV in a drainage (gully) feature. It included two SWMUs (the Ash Pile and Incinerator and the RD-9 Area Ultraviolet/Hydrogen Peroxide Treatment System, both of which have been removed) and two Areas of Concern (the Building 515 STP Area and the Building 211 Leach Field). Potential chemicals used at the AP/STP include solvents, oils, fuels, metals, PCBs, dioxins, and asbestos.
3. The Alfa/Bravo AIG is located in the central portion of Area II. The Alfa/Bravo AIG includes the Alfa Area, Bravo Area, Alfa/Bravo Fuel Farm (ABFF), SPA, and Hazardous Waste Storage Area (HWSA).
    a. The Alfa Area is located in the central-eastern portion of Area II and included three engine test stands (designated an SWMU) and associated pipelines. It also included support buildings, debris areas, ASTs (three of which were designated an SWMU), septic leach fields, the Alfa Skim Pond and Alfa Retention Pond (also an SWMU; ponds received fuel- and solvent-impacted cooling waters from the test stands). Potential chemicals used at the Alfa Area include solvents (large quantities of TCE were used to flush the engines at the test stands), oils, fuels, PCBs, and oxidizers.
    b. The Bravo Area is located in the central-western portion of Area II and also included three engine test stands (designated an SWMU) and associated pipelines, as well as support buildings, debris areas, ASTs (including the Bravo Waste Tank that is an SWMU), septic leach fields (two designated as Areas of Concern), former groundwater air-stripping towers (an SWMU), and the ABSP and Bravo Skim Pond (both SWMUs). The ABSP is a RCRA-closed regulated unit under post closure care, and the drainage piping beneath the ABSP is designated as an Area of Concern. Potential chemicals used at the Bravo Area include solvents (including large quantities of TCE), oils, fuels, and oxidizers.

c. The ABFF, which is designated an Area of Concern, is located in Area II, northwest of the Bravo Area. It included petroleum-based fuel ASTs and associated pipelines and pumps to support the Alfa and Bravo Test Stands. Potential chemicals used at the ABFF include solvents, fuels, lead-based paint, and PCBs.

d. The SPA is located in Area II, just west of the ABFF, and expands into Areas III and IV to the west. The SPA was used to store bulk quantities of hazardous materials associated with the test stand use. It contains two RCRA-closed surface impoundments under post-closure care, SPA-1 and SPA-2 (designated as SWMUs), which were used to contain and treat hazardous wastes. The support area between the two impoundments is designated as the SPA Area of Concern. Potential chemicals used at the SPA are wide-ranging and include solvents, fuels, acids, oxidizers, formaldehyde, fluoride, PCBs, energetics, n-nitrosodimethylamine (NDMA), metals, and pesticides.

e. The HWSA consists of two SWMUs, the HWSA Container Storage Area (a RCRA-permitted unit used to store drummed wastes, which is a DTSC-certified closed unit) and the Waste Coolant Tank. Potential chemicals used at the HWSA include solvents, oils, fuels, acids, oxidizers, bases, and metals.

4. The Coca/Delta AIG is located in the southern portion of Area II. The Coca/Delta AIG includes the Coca Area, Delta Area, Coca/Delta Fuel Farm (CDFF), R-2 Ponds, and the Propellant Load Facility (PLF).

   a. The Coca Area is in the southeast portion of Area II and included four engine test stands (designated as an SWMU) and associated pipelines. It also included support buildings, debris areas, ASTs, USTs, leach fields, transformers, and the Coca Skim Pond (an SWMU). Potential chemicals used at the Coca Area include solvents (including large quantities of TCE), oils, fuels, metals, fluoride, energetics, formaldehyde, Freon, PCBs, dioxins, and oxidizers.

   b. The Delta Area is in the southwest portion of Area II and included three engine test stands (designated an SWMU) and associated pipelines. It also included support buildings, debris areas, ASTs, USTs, a leach field (an Area of Concern), transformers, Delta Area Groundwater Extraction/Treatment Unit (including a Purge Water Tank and Delta Air Stripping Towers, designated as SWMUs), fluorine scrubber, and the RCRA-closed surface impoundment Delta Skim Pond under post closure care (an SWMU). Potential chemicals used at the Delta Area include solvents (including large quantities of TCE), oils, fuels, metals, anions, energetics, PCBs, dioxins and furans, Freon, amines, acids, bases, and oxidizers.

   c. The CDFF, which is designated an Area of Concern, is in the southwestern portion of Area II and extends into Area III. It included petroleum-based fuel ASTs and associated pipelines and pumps to support the Coca and Delta Test Stands. Potential chemicals associated with the operations conducted at the CDFF area include solvents, oils, fuels, metals, anions, PCBs, dioxins and furans, formaldehyde, acids, and bases.

   d. The R-2 Ponds are an SWMU located northwest of the Delta Area. The two adjacent ponds (R-2A and R-2B) received drainage water from skim and retention ponds in Areas I through IV. Potential chemicals associated with water received in the R-2 Ponds include solvents, oils, fuels, PCBs, dioxins and furans, energetics, fluorine, and nitrates.

   e. The PLF is north of the Delta Area and east of the R-2 Ponds. It was the control center for the Delta Test Area and contained three SWMUs: the PLF Waste Tank, the PLF Ozonator Tank, and the PLF Surface Impoundment. It also contains an Area of Concern leach field. Potential chemicals associated with the operations conducted at the PLF include solvents, oils, fuels, metals, chromium VI, perchlorate, NDMA, energetics, PCBs, dioxins and furans, formaldehyde, and anions.

Details regarding the background, operational history, and potential release areas associated with the former LOX Plant, B204/ELV, Alfa/Bravo, and Coca/Delta AIGs can be found in the NASA Groundwater RFI Report (NASA, 2017a).

1.3 NASA Area Geology

SSFL is located in the Western Transverse Ranges physiographic province of southern California. The geology and physiographic expression of the Western Transverse Ranges reflects at least 70 million years of geologic history. Within this province, the region encompassing SSFL includes the Simi and Thousand Oaks Valleys, the western San Fernando Valley, the Simi Hills, and portions of the Santa Susana and Santa Monica mountains (MWH, 2009)

1.3.1 Geologic Units

The primary geologic units present at the NASA-administered portions of SSFL are the unconsolidated Quaternary alluvium/colluvium deposits and the underlying Late-Cretaceous age Chatsworth Formation (MWH, 2007). Where present, alluvium/colluvium deposits overlie the Chatsworth Formation as a relatively thin and discontinuous layer in the valley bottoms and other localized channelized areas, such as ephemeral drainage features. The thickness of the Quaternary deposits is typically 1 to 5 feet thick, but in some localized areas, it is more than 15 feet thick. The alluvium consists of a mixture of sand and silty sand, with minor amounts of silt and clay.

Within the NASA-administered area, the Chatsworth Formation is generally divided (from oldest to youngest) into Sandstone 1, Shale 2 Members, and Sandstone 2. The upper portion of Sandstone 1 includes the Sage Member, which underlies a portion of the NASA-administered area and which also includes the Upper and Lower Bravo Beds. Shale 2 Members include a Lower Shale 2 Member and Upper Shale 2 Member, which are separated by a sandstone layer. Sandstone 2, which overlies the Upper Shale 2 Member, includes the Silvernale Member, SPA Member, Lower Burro Flats Member, ELV Member, and the Upper Burro Flats Member. The members are identified based on general grain size with the finer-grained members (Upper and Lower Shale 2 Members, SPA Member, and ELV Member) and beds (Lower and Upper Bravo Beds within the Sage Member) separating the coarser-grained members (Sage, Silvernale, Lower and Upper Burro Flats Members).

The Chatsworth Formation consists primarily of massively bedded, prominent sandstones interbedded with thinner beds of shale, siltstone, and conglomerate. However, based on the results of field mapping and geophysical logging in the NASA-administered areas (NASA, 2017a; CH2M, 2017), the interbeds consist of siltstone and conglomerate, with no shale identified. The sandstone generally consists of fine- to medium-grained angular sand. Weathered surfaces of the sandstone may crumble, whereas fresh surfaces remain well cemented. The siltstone, which was previously mapped as “shale,” consists of laminated to thinly bedded silt with minor amounts of clay. Weathered surfaces are fissile and the siltstone may be mistaken for shale. Like shale, the layered siltstone represents a potential barrier or semi-permeable barrier to groundwater flow because of its lower hydraulic conductivity in relation to the encasing sandstone.

1.3.2 Geologic Structures

The Chatsworth Formation has undergone a complex history of regional tectonic stresses, exposing it to multiple orientations of compressional, extensional, and shear forces. Exposures of the Chatsworth Formation present across the Simi Hills and Santa Susana Mountains indicate that it is synclinally folded with an approximately east-west-striking axis. SSFL is located on the south limb of this west-plunging syncline (Dibblee, 1992). Bedding orientations at SSFL are locally variable but typically strike approximately N70°E and dip 25 to 35 degrees to the north-northwest (Aydin and Cilona, 2014). The average bedding plane strikes about N65°E with a dip of 28 degrees northwest (NASA, 2017a), which is within the range of the previously measured orientation at SSFL.

Additionally, SSFL has been subjected to local stresses, including faulting and erosional unloading. As a result, SSFL and its vicinity are traversed by numerous, steeply dipping to near-vertical geologic structures, such as faults and joints, of various orientation, length, displacement, and type. Structural features developed within the Chatsworth Formation occur both in large-scale features, such as folds and fractures (joints and faults), and in small-scale features, such as microfractures and contorted bedding. Although the joint orientation across the site is variable, the predominant orientation is about N30˚E with a dip of 65 degrees southeast, which is about 90 degrees to the bedding plane (that is, the pole lies along the arc of the bedding plane) (NASA, 2017a; CH2M, 2017). The relationship between the bedding planes and predominant joint orientation suggests that most of the joints may be related to the regional tectonic fabric.

The primary geological faults identified in the NASA-administered portion of SSFL include the Burro Flats Fault Zone and Bell Canyon Faults south of the Coca/Delta AIG, the Coca Fault within the Coca/Delta AIG, the Skyline Fault, which traverses the Coca/Delta and Alfa/Bravo AIGs, and the North Fault Zone, which extends through the former LOX Plant and B204/ELV AIGs. Other than the Skyline Fault, which trends roughly north-south, the faults trend roughly east-west. The Tank Structure and the Alfa Deformation Band did not display indications of displacement and, therefore, are identified as joints. Although no obvious fault features were noted in the field during mapping of the Delta Deformation Band, a review of the boring and geophysical logs from wells drilled adjacent to the deformation band show subsurface voids and large, open fractures that suggest the presence of a fault (NASA, 2017a).

1.4 NASA Area Hydrogeology

The hydrogeologic conceptual models for the AIGs are discussed in detail in the NASA Groundwater RFI Report (NASA, 2017a). A summary is presented in the following sections.

1.4.1 Hydrostratigraphic Units

Hydrostratigraphic units (HSUs) at NASA Areas I and II include, from oldest to youngest, the Sage Member of Sandstone 1 (including the fine-grained Upper and Lower Bravo Beds), the Shale 2, the Silvernale, SPA, Lower Burro Flats, ELV, and Upper Burro Flats Members of Sandstone 2, the Shale 3, and the alluvium/overburden. In general, the coarser-grained sandstone units act as aquifers (saturated formations that have sufficient permeability to supply groundwater in quantities of economic value), while the finer-grained siltstone units act as aquitards (a low permeability formation that can store groundwater and/or slowly transmit groundwater between overlying/underlying aquifers). Groundwater flow and chemical of concern (COC) transport can also be influenced by a variety of other structural and lithologic features, including the following (NASA, 2017a):

- Fault zones, which can act as zones of increased permeability (conduits for preferential groundwater flow), zones of decreased permeability (barriers to groundwater flow), or a combination of the two
- Fracture zones and networks, which can result in zones of increased permeability and provide flow paths across fine-grained units
- Bedding planes, which can create preferential flow paths
- Coarse-grained sandstone and/or conglomerates, which may have sufficient primary porosity to transmit groundwater and/or COCs
- Interbedded fine-grained units, which can act as aquitards
- Open boreholes, which can create preferential vertical flow paths between HSUs

1.4.2 Aquifer Properties

The aquifer system in NASA-administered Area I and Area II is characterized as a dual-porosity system, consisting of relatively highly fractured/faulted sandstone of varying grain size. The effective matrix (or primary) porosity of unweathered sandstone at SSFL ranges from approximately 4 to 20 percent with a

mean of approximately 14 percent (MWH, 2009). The total porosity of the fracture network (that is, secondary porosity) at SSFL was previously estimated to be between 0.0005 to 0.01 (MWH, 2000). The conceptual model for the dual-porosity aquifer system at SSFL is such that the primary (matrix) porosity acts primarily as a reservoir for storage, while the secondary (fracture networks) porosity acts primarily as a conduit for flow. However, the matrix porosity can transmit fluid and portions of the fracture network can act as reservoirs for storage.

Details of hydraulic conductivity and transmissivity estimates for the NASA AIGs are provided in the NASA Groundwater RFI Report (NASA, 2017a). Both these terms are used to describe the capacity of an aquifer to transmit water. Results from depth-discrete packer testing in open boreholes by HSU suggest that the geometric mean hydraulic conductivity within the aquifer units (averaging about 10^{-4} to 10^{-5} centimeters per second [cm/sec]) was generally one order of magnitude or more greater than that of the finer-grained units (averaging about 10^{-5} to 10^{-6} cm/sec).

Injection aquifer testing conducted at NASA AIGs (NASA, 2017a) yielded bulk transmissivity estimates on the order of 5,000 to 7,000 square feet per day (ft^2/day) at the former LOX Plant AIG, and 400 to 500 ft^2/day at the B204/ELV and Alfa Bravo AIGs. Coca/Delta AIG aquifer transmissivity is inferred to be lower than in other portions of NASA Area I and Area II.

Storativity (or storage coefficient) is the volume of water released from (or taken into) storage in the aquifer system per unit area per unit change in head. Estimates of storativity at the B204/ELV and Alfa/Bravo AIGs are similar (generally in the 10^{-2} to 10^{-4} range), while higher storativity values were estimated at the former LOX Plant AIG (generally within the 10^{-1} to 10^{-3} range).

1.4.3 Groundwater Occurrence and Flow

Groundwater beneath SSFL is divided into two categories (MWH, 2003):

- **Near-surface Groundwater (NSGW)** – Groundwater that occurs within the alluvium and weathered bedrock
- **Chatsworth Formation Groundwater (CFGW)** – Groundwater that occurs in the competent bedrock aquifer and is deeper than the NSGW

The NASA Groundwater RFI Report (NASA, 2017a) presents the distribution of NSGW wells, CFGW wells, and seeps/springs within and near NASA-administered Area I and Area II.

Sources of recharge to the aquifer systems underlying NASA-administered Area I and Area II include deep percolation of precipitation, imported or applied water (such as the former Alfa Spray fields), water from leaking pipes, or losses from surface water bodies (such as streams or ponds). Once this infiltrating water encounters the CFGW, it migrates along one of two general flow pathways: (1) vertically to the deeper regional aquifers, or (2) outward toward and potentially discharging to seeps, springs, and/or phreatophytes located along the SSFL perimeter (MWH, 2009). Subsurface groundwater also inflows to the AIGs from hydraulically upgradient areas. Groundwater pumping is the largest hydraulic stress (outflow component) that has influenced groundwater elevations at SSFL. Prior to 1984, groundwater was extracted primarily for water supply purposes. More recently (mid-1980s through early 2000s), smaller volumes of groundwater have been extracted as part of interim remedial activities (MWH, 2009).

The occurrence and spatial extent of NSGW is highly climate dependent; there is a larger extent of NSGW during wetter periods and a more limited extent under drier conditions. NSGW occurs under two general conditions with respect to the CFGW system:

- Perched, with groundwater elevations higher than those in the underlying CFGW aquifer
- Continuous, having similar groundwater elevations as the CFGW aquifer

Where present, NSGW flow generally follows surface water drainage patterns. The majority of the NSGW system in NASA-administered Areas I and Area II is ephemeral with piezometers observed to be dry in years

of limited precipitation. The exceptions to this are the ELV and AP/STP of the B204/ELV AIG, portions of the Alfa Drainage at the Alfa/Bravo AIG, and the drainage south of the Coca/Delta AIG, where NSGW is temporally persistent (NASA, 2017a). NSGW extent is shown in the NASA Groundwater RFI Report (NASA, 2017a).

In addition to recharge from precipitation, the occurrence and movement of CFGW in the Sage Member, Shale 2 Members, Silvernale Member, Lower Burro Flats Member, and Upper Burro Flats Member in NASA Areas I and II are influenced by groundwater extraction, major fault zones, bedding plane fractures, and fine-grained units (NASA, 2017a). The CFGW flow regime can be divided into two broad categories based on HSU:

- Within the Shale 2, Silvernale, SPA, Upper and Lower Burro Flats, and ELV Members of Sandstone 2 in the northern portion of the site, flow is generally to the north (for example, at the B204/ELV AIG and the northern portion of the Alfa/Bravo AIG). Although portions of the former LOX Plant AIG overlie these HSUs, groundwater flow is highly influenced by the North Fault Zone. In this area, CFGW groundwater converges on the North Fault Zone (from the north and south) and then flows west.
- Within the Sage Member of Sandstone 1 in the central portion of the site, groundwater flow is dominated by a large pumping depression created during the groundwater extraction period in the mid-1980s through early 2000s. Groundwater near the Alfa/Bravo AIG flows toward this depression from the south and northwest and then flows east-northeast. In the southern portion of the site (in the Coca/Delta AIG), groundwater flow within the Sage Member is dominated by a groundwater divide located just south of the Coca Fault. North of this divide, groundwater flows to the north; south of the divide, groundwater flows to the south toward the Burro Flats Fault Zone. The Burro Flats Fault Zone is generally a barrier to groundwater flow and forces groundwater upward.

Vertical hydraulic gradients are generally downward or neutral in the NASA SSFL AIGs. However, upward vertical hydraulic gradients are present north of the B204/ELV AIG in the artesian well pair RD-68A/B, and in the groundwater discharge area south of the site near the Burro Flats Fault system (NASA, 2017a).

1.4.4 Site Conceptual Model

The primary lithology at the site is fractured and faulted sandstone and shale. The groundwater system is replenished through a relatively small amount of rainfall infiltrating through the vadose zone and migrating slowly through a network of ubiquitous but small, interconnected fractures that cause groundwater to mound beneath the site and generate static groundwater levels hundreds of feet above the surrounding valleys. This mounded groundwater condition results in a complex flow field characterized by numerous potential pathways between the source areas and downgradient receptors. Most of these pathways have some combination of downward and outward oriented flow. These components of flow influence groundwater migration deeper into the regional groundwater system. Outward flow could exit the site through convergence at seeps, springs, and phreatophytes. COCs have not been detected at the majority of seeps and springs surrounding the site. Groundwater in storage at the site will also migrate downward toward the base of SSFL and subsequently outward toward the valleys within the regional groundwater system.

Historically, contamination associated with rocket engine testing activities, primarily TCE, was released at SSFL into surface water drainages and ponds, as well as directly discharged to the ground surface. This contamination entered the subsurface though surface water infiltration and deep percolation of precipitation, creating vadose zone sources as well as deeper groundwater COC plumes. Some residual nonaqueous phase TCE may still exist within the bedrock matrix in higher-strength source areas; however, conclusive evidence of mobile dense nonaqueous phase liquid at the site has not been observed. The transport of contamination through the Chatsworth Formation is limited because of the presence of rock matrix blocks between faults and fractures that have a relatively high porosity and low permeability. This rock matrix represents a large storage reservoir for COCs and limits their mobility through the process of matrix diffusion. Therefore, matrix diffusion is the dominant mechanism that has historically isolated the

COC mass from the advecting groundwater, limiting the extent of the migration of COCs from source areas. Currently, vadose zone sources continue to transfer volatile organic compound (VOC) mass to the water table through predominantly vertical migration pathways. Groundwater plumes within the saturated zone migrate laterally in response to horizontal and vertical hydraulic gradients, as well as within bedrock fracture pathways.

As contamination moves through the Chatsworth Formation bedrock, the rate of migration is governed by transport processes of advection, dispersion, adsorption to aquifer solids and mineral surfaces, and degradation by biotic and abiotic processes. The migration rates are also attenuated by diffusion into the bedrock matrix. In most areas of the site, natural attenuation processes are sufficient to prevent the additional spreading of the plume footprints. The influence of these natural attenuation processes on plume stability are inferred through observations of stable or declining VOC concentrations in groundwater over time, the presence of TCE daughter products, changes in carbon isotope ratios in TCE and its daughter products that confirm degradation, the documented presence of groundwater bacteria known to degrade TCE and its daughter products, and the lack of continued plume expansion over the last decade or more (NASA, 2017a).

1.5 NASA Area COC Nature and Extent

1.5.1 Former LOX Plant AIG COC Nature and Extent

This subsection provides a brief summary of the nature and extent of COCs in the groundwater at the former LOX Plant AIG. Detailed information on the former LOX Plant AIG nature and extent is provided in the NASA Groundwater RFI Report (NASA, 2017a). The groundwater COCs at the former LOX Plant AIG are TCE, cis-1,2-dichloroethene (DCE), vinyl chloride (VC), and 1,4-dioxane. These COCs were identified by completing human health and ecological risk assessments for exposure to groundwater, seeps, and bedrock vapor for the former LOX Plant AIG (NASA, 2017b). The former LOX Plant AIG COC combined groundwater plume extent, as well as the individual COC estimated groundwater screening level (GSL) boundaries, are presented on Figure 1-2. These plumes were assessed by using COC concentration data collected during a 2015–2016 comprehensive groundwater monitoring event for the NASA Groundwater RFI Report (Appendix A; NASA, 2017a). This plume figure shows combined NSGW and CFGW plumes because there are no distinct NSGW plumes in the former LOX Plant AIG. One primary plume exists in the CFGW for each of the four COCs at this AIG (except VC), and all are primarily associated with the former LOX Plant AIG source area (LOX-SA-1). From LOX-SA-1, COC plumes migrate south toward the North Fault Zone, then to the west-northwest along the North Fault Zone, terminating prior to reaching WS-13 or the B204/ELV AIG. Isolated exceedances of 1,4-dioxane have been detected beyond its main plume body at RD-82 and WS-04A; however, these exceedances are low level and anomalous (NASA, 2017a).

COC plume movement observed at the former LOX Plant AIG in the past has been to the west-northwest, facilitated by the presence of the North Fault Zone. Several lines of evidence suggest that natural attenuation is occurring in this AIG, including the presence of daughter products, iron-reducing conditions observed in the groundwater at many locations, the presence of microbes with functional genes known to be capable of both anaerobic and aerobic degradation of TCE and its daughter products, and enriched TCE and cis-1,2-DCE caron-13 isotope values relative to newly manufactured TCE. Analytical groundwater data indicate the TCE, VC, and 1,4-dioxane plumes are stable, although the cis-1,2-DCE plume has the potential for limited future expansion as the remaining TCE mass at the site degrades to cis-1,2-DCE (NASA, 2017a). However, no COCs have been detected above GSLs in seeps adjacent to the former LOX Plant AIG (Boeing, 2015; NASA, 2017a), and there is no known threat of offsite plume migration at the former LOX Plant AIG (NASA, 2017a).

1.5.2 B204/ELV AIG COC Nature and Extent

This subsection provides a brief summary of the nature and extent of COCs in the groundwater at the B204/ELV AIG. Detailed information on the B204/ELV AIG nature and extent is provided in the NASA

Groundwater RFI Report (NASA, 2017a). The groundwater COCs at the B204/ELV AIG are TCE, cis-1,2-DCE, VC, 1,4-dioxane, 1,2,3-trichloropropane (TCP), lead, and cadmium. These COCs were determined by completing a risk assessment (NASA, 2017b). The B204/ELV AIG COC combined groundwater plume extent, as well as the individual COC estimated GSL boundaries, are presented on Figure 1-3 (includes NSGW and CFGW plumes). These plumes were assessed by using COC concentration data collected during a 2015–2016 comprehensive groundwater monitoring event for the NASA Groundwater RFI Report (Appendix B; NASA, 2017a). The extent of groundwater COCs in the NSGW is mostly confined to the ELV in a single commingled plume focused around wells PZ-139, PZ-140, and PZ-141 that is associated with source areas BE-SA-1 and BE-PSA-5 (Figure 1-3). Three main solvent-related COC plumes exist within the CFGW: (1) one originating in the Building 204 Area that extends north to RD-56A, (2) one within the ELV that extends northwestward and terminates prior to reaching ND-123, and (3) one in the AP/STP that is associated with multiple sources and extends northeastward, terminating prior to reaching ND-126. The B204/ELV AIG Data Evaluation Report (Appendix B; NASA, 2017a) concluded that there were no cohesive plumes for cadmium or lead as the detections were sporadic. However, GSL exceedances of lead and cadmium in groundwater are contained within the footprint of the other COC plumes (NASA, 2017a).

Similar to the former LOX Plant AIG plumes, there are multiple lines of evidence suggesting that natural attenuation is occurring in the B204/ELV AIG. Groundwater COC concentrations across the B204/ELV AIG show decreasing or stable trends, suggesting that plumes in the area are generally stable, with the exception of cis-1,2-DCE in RD-56A. Although this well exhibits small increases in cis-1,2-DCE over time, the increases are the result of degradation of TCE to cis-1,2-DCE. Since TCE concentrations in RD-56A are declining, cis-1,2-DCE concentrations are also anticipated to stabilize in the near future (NASA, 2017a).

The ultimate pathway for potential offsite COC migration under current hydraulic conditions is through seep water that emerges to the north of the B204/ELV AIG. To date, 15 seep and seep well clusters have been identified and/or installed in the general vicinity of the B204/ELV AIG, the majority of which occur outside of SSFL property boundaries to the north of the AIG. Over the period of record, groundwater COCs have been detected at seep OS-08/S-25 and seep well SP-29C (Boeing, 2015) and more recently at seep well SP-30D (NASA, 2017a). However, seep cluster COC detections are sporadic and below GSLs. Seep and seep well detections (most flagged as estimated concentrations) include the following:

- TCE was detected at seep OS-08/S-25 in both 1987 (1 microgram per liter [µg/L]) and 1997 (0.66 µg/L) but not in subsequent samples.
- 1,4-dioxane was detected at seep well SP-29C in August 2015 (0.92 µg/L); this location was nondetect for 1,4-dioxane in December 2015.
- TCE and cis-1,2-DCE were detected at seep well SP-30D in 2016 (0.52 µg/L and 0.59 µg/L, respectively). The two samples collected prior to these 2016 seep well SP-30D samples were nondetect for TCE and cis-1,2-DCE.
- Cadmium was detected at SP-25B, SP-25C, and SP-30B at concentrations of 0.08, 0.026, and 0.03 µg/L respectively, in 2011 (well below the GSL of 0.2 µg/L). However, it was nondetect at a reporting limit of 0.1 µ/L in subsequent samples.

Groundwater COCs have not, and are not expected to, reach the B204/ELV AIG-related seeps at concentrations above their GSLs because of these low and sporadic detections (NASA, 2017a).

1.5.3 Alfa/Bravo AIG COC Nature and Extent

This subsection provides a brief summary of the nature and extent of COCs in groundwater at the Alfa/Bravo AIG. Detailed information is provided in the NASA Groundwater RFI Report (NASA, 2017a). The groundwater COCs at the Alfa/Bravo AIG are TCE, cis-1,2-DCE, trans-1,2-DCE, VC, 1,4-dioxane, and NDMA, which were determined by completing a risk assessment (NASA, 2017b). The Alfa/Bravo AIG COC combined groundwater plume extent, as well as the individual COC estimated GSL boundaries, are presented on Figure 1-4 (includes

NSGW and CFGW plumes). These plumes were assessed by using COC concentration data collected during an early 2016 comprehensive groundwater monitoring event for the NASA Groundwater RFI Report (Appendix C; NASA, 2017a). In the Alfa Area, most COCs in the NSGW are focused around source area AB-SA-3A (associated with the test stands), extending downgradient to the west-southwest just beyond well RD-49A. In the Bravo Area, NSGW COCs are associated with the Bravo Skim Pond. cis-1,2-DCE presently extends downgradient from both the Bravo Skim Pond and AB-SA-3A in the Alfa Area, mirroring the surface drainages in these areas and converging below the Alfa Skim Pond and ABSP (NASA, 2017a).

Two primary COC plumes exist within the CFGW in the Sage Member: (1) one originating in the Alfa Area that is primarily associated with source area AB-SA-3A (associated with the test stands) and extends northwest to encompass ND-137B, and (2) one in the Bravo Area that is related to multiple sources (the Bravo Skim Pond, AB-SA-4A, and potentially AB-PSA-4B and AB-PSA-5) and has generally migrated to the northwest and northeast, encompassing ND-132, HAR-20, and ND-133. The cis-1,2-DCE plume in the Sage Member presently extends from the Bravo Area and associated sources to the northeast, where it is commingled with cis-1,2-DCE associated with the Alfa Test Stands and spillways (AB-SA-3A and AB-PSA-3B through AB-PSA-3E) moving to the north and west. As a result of historical pumping and ongoing TCE degradation, the eastern portion of the cis-1,2-DCE plume extends from the Alfa Area to WS-06. Within the Silvernale Member, a small cis-1,2-DCE plume extends from HAR-21 to the northwest towards well HAR-06 in the SPA (NASA, 2017a).

The same multiple lines of evidence described for the Former LOX Plant AIG suggest that natural attenuation is occurring at the Alfa/Bravo AIG. The mechanism for COC transport near wells WS-09 and RD-04 appears to be discrete factures that provide a hydraulic connection between nearby source areas to these locations, as evidenced by historical observations of rapidly increasing TCE concentrations in both wells as groundwater levels recovered from several periods of regional pumping. Many of the primary COC concentrations in these two wells have shown continued increases since the 2003−2005 period. In general, groundwater COC concentrations across the Alfa/Bravo AIG show decreasing or stable trends, suggesting that the plumes in the area are generally stable. In the limited areas where small increases have been observed, it is likely that concentrations will stabilize in the near future with extremely limited additional expansion of current plume footprints (NASA, 2017a).

Given the central location of the Alfa/Bravo AIG within NASA-administered Area II, no pathways exist from plumes within this AIG to seeps located to the north or south, and no COC migration beyond the boundaries of the AIG is anticipated (NASA, 2017a).

1.5.4 Coca/Delta AIG COC Nature and Extent

This subsection provides a brief summary of the nature and extent of COCs in the groundwater at the Coca/Delta AIG. Detailed information on the Coca/Delta AIG nature and extent is provided in the NASA Groundwater RFI Report (NASA, 2017a). The groundwater COCs for the Coca/Delta AIG are TCE, cis-1,2-DCE, trans-1,2-DCE, VC, NDMA, 1,4-dioxane, and formaldehyde. These COCs were determined by completing a risk assessment (NASA, 2017b). The Coca/Delta AIG COC combined groundwater plume extent, as well as the individual COC estimated GSL boundaries, are presented on Figure 1-5. These plumes were assessed by using COC concentration data collected during a 2015/2016 comprehensive groundwater monitoring event for the NASA Groundwater RFI Report (Appendix D; NASA, 2017a).

Two primary COC plumes exist within the Coca/Delta AIG (Figure 1-5). In the Coca Area, the TCE plume extends from Coca Test Stand 4 westward down the valley, past the Coca Skim Pond. In the Delta Area, the TCE plume extends northwestward from the Delta Area and Delta Skim Pond toward the R-2 Ponds, and south-southwestward toward the WS-09A area and the Southwest Drainage near the Burro Flats Fault Zone. Existing data sets suggest that Boeing Area III sources contribute to the COC plumes in the NASA-administered Area II - Delta Area, in addition to plume source contributions within the Delta Area itself (NASA, 2017a; Boeing, 2017). The exact origin, transport direction, extent, and shape of such COC mass contributions from sources within Boeing Area III are not shown and are unknown at this time. The

northwestern-most component of this plume is likely related to potential sources in Area III, from which TCE mass has migrated southeastward across property lines and commingled with mass originating from Delta Area sources. The other COC plumes are roughly within the TCE plume footprint; however, the 1,4-dioxane and cis-1,2-DCE plumes extend farther downgradient (NASA, 2017a).

As with the other AIGs, several lines of evidence suggest that natural attenuation is occurring at the Coca/Delta AIG. COC plumes in the area are either currently stable, or will experience very limited growth in future. The Coca Area plume that migrates north-northwest from the Coca Test Stands is not expected to migrate off of NASA Area II property. The Delta Area/R-2 Ponds-related COC plume migrating down the Southern Drainage has not, and is not expected to, migrate farther south than well RD-06 (located south of Area II in the SSFL buffer zone) at concentrations above the GSLs (NASA, 2017a).

To date, 14 seeps and pools have been identified in the general vicinity of the Coca/Delta AIG, the majority of which are located inside the SSFL property boundaries to the south of the Coca/Delta AIG. Based on the site conceptual model of groundwater flow and COC transport at the Coca/Delta AIG (discussed further in the following section), a majority of seeps and seep well clusters to the south of the Coca/Delta AIG could potentially be along a COC migration pathway originating from Coca/Delta AIG source areas, as well as source areas located in Boeing Area III (NASA, 2017a).

The northernmost seeps and seep well clusters in the Southwest Drainage Area (namely, SP-890, SP-881, and SP-882) are the locations of primary concern. In 2015 and 2016, SP-890 contained concentrations of TCE, cis-1,2-DCE, trans-1,2-DCE, VC, and/or 1,4-dioxane above their respective GSLs. Concentrations of these COCs are detected at lower concentrations (1,4-dioxane, cis-1,2-DCE) at SP-881, or not at all. Further declines in concentrations occur between SP-881 and SP-882, such that the concentrations at this most downgradient well are less than 20 times (cis-1,2-DCE) or less than 5 times (1,4-dioxane) their GSLs. In addition to this pattern of significant concentration decline, the cross-sectional volume of the zone with detections decreases. Upgradient of the Burro Flats Fault Zone, COCs are detected several hundred feet below ground; downgradient of the Fault Zone, the deepest detection is less than 100 feet, and further south, less than 50 feet (NASA, 2017a).

1.6 NASA-specific Sitewide Groundwater Monitoring Program

The SSFL sitewide groundwater monitoring program (Haley & Aldrich, 2010a) is being updated specific to NASA areas to better support current site needs. The current NASA-specific sitewide groundwater monitoring program reflects sampling needs post-submittal of the NASA Groundwater RFI Report (NASA, 2017a), which provides an updated site conceptual groundwater model. The objectives of NASA's sitewide groundwater monitoring program include:

- Collecting data to support continued plume stability evaluations. Groundwater sampling analytical and water quality parameters are shown in Table 1.
- Collecting data to provide sentinel monitoring for potential offsite migration. Wells identified as sentinel monitoring locations are shown in Table 2.
- Collecting data to support remedial alternative evaluations associated with the CMS and CMI.
- Collected data to support development of long-term monitoring programs.

The nature and extent of the AIG COC plumes and their fate and transport evaluations described in the NASA Groundwater RFI Report (NASA, 2017a) were used to guide the groundwater well monitoring network proposed in this NASA-specific Sitewide GWQSAP.

SECTION 2

NASA-specific Sitewide Groundwater Monitoring Program

This section presents the proposed groundwater monitoring network, analytes, and sample frequency for each NASA AIG for the NASA-specific sitewide groundwater monitoring program.

2.1 Purpose and Scope

This NASA-specific Sitewide GWQSAP presents procedures for groundwater elevation and groundwater quality monitoring at the four NASA AIGs. Groundwater quality monitoring is split into two categories:

- **COC Monitoring:** This monitoring is to evaluate time-series trends of AIG-specific COCs (NASA, 2017a) at AIG monitoring wells to aid with AIG-COC plume stability and potential offsite migration evaluations. COCs by AIG are listed in Table 1. Monitoring stations in the proposed network will include COC monitoring on an annual basis (discussed further below).
- **Natural Attenuation Monitoring:** This includes sampling for parameters that provide information about geochemical conditions relevant to natural degradation processes that are occurring in the SSFL aquifer associated with chlorinated VOCs. This sampling is proposed once every two years (biannually) to support decisions about a potential future long-term monitoring network (discussed further in the following sections).

The scope of the NASA-specific Sitewide GWQSAP includes the following elements:

- Procedures describing the process of sampling
- The monitoring locations
- The analytical suite associated with each AIG and each sampling type
- The frequency of monitoring
- Analytical data analysis/evaluation
- Program reporting

2.2 Groundwater Monitoring Network

2.2.1 Monitoring Locations

The wells selected for the NASA-specific sitewide groundwater monitoring program are located near or in groundwater impact areas. These wells are intended to monitor water quality and/or groundwater elevations at each AIG and allow for the detection of potential offsite migration of COCs. Selected monitoring wells are shown on Figure 2-1 and listed in Table 2. Rationale for the sample locations is detailed in Table 2. Well construction information for each of the selected wells is provided in Table 3.

Water level measurements and sample collection will be conducted at each of these wells in accordance with the monitoring frequency described in Table 2 (typically quarterly). Laboratory analysis of the samples will include monitoring parameters listed in Table 1 (AIG-specific) and will be performed in accordance with the requirements of the Field Sampling Plan (FSP) (included as Appendix A), Quality Assurance Project Plan (QAPP) (Haley & Aldrich, 2010a), and QAPP addendum (included as Appendix B). Future modifications to this program will be developed, as appropriate, to support the objectives of the NASA-specific sitewide groundwater monitoring program.

2.2.2 Monitoring Frequency

Groundwater concentrations of COCs and natural attenuation parameters will be monitored in wells included in the NASA-specific sitewide groundwater monitoring program, as indicated in Table 2. Sampling

will occur once a year for AIG-specific COCs, and once every 2 years for natural attenuation parameters. Annual AIG-specific COCs monitoring is appropriate because the site groundwater COC sources are significantly aged and no new sources are being created at the site. Sampling will occur in either first or second quarter of each year. The long history of groundwater sampling in the NASA-administered areas indicates the COC plumes are generally stable and rapid changes in groundwater concentrations at each well are not occurring (NASA, 2017a). Every other year, natural attenuation parameter monitoring is also appropriate to support interim remedial decisions prior to a formal monitored natural attenuation sampling program implementation. Experience at SSFL and other similar sites indicates that once plumes are relatively stable, conditions that influence natural attenuation processes are also stable and do not exhibit rapid changes over time. Further, previous sampling for natural attenuation parameters has indicated that oxidation reduction conditions vary spatially within the impacted groundwater system across the SSFL, both laterally and vertically, but conditions at specific wells tend to be relatively stable and less variable than the sitewide variability.

Water levels will be measured quarterly to obtain seasonal information, concurrent with groundwater sampling events where applicable.

2.2.3 Monitoring Parameters

Monitoring parameters are selected on a well-by-well basis. Site use history information, historical water quality data, and NASA Groundwater RFI Report (NASA, 2017a) evaluations contributed to the selection of monitoring parameters for each well in the monitoring network. In general, wells located in sentinel monitoring locations or outside of a plume centerline were selected for COC sampling only (to support overall plume nature, extent, and stability/migration evaluations), and wells located within or associated with plume sources or centerlines were selected for sampling of natural attenuation parameters in addition to COCs. Monitoring parameters, analytical methods, and other pertinent sampling information for wells within the sitewide monitoring network are listed in in Table 1. Additionally, sampling containers, preservation requirements, and holding times for each analyte are detailed in Table B-2 of Appendix B (the QAPP addendum).

2.2.4 Monitoring Elements

2.2.4.1 Well Condition

Prior to groundwater level gauging and sampling, each well will be visually inspected for proper identification, surface seal integrity, security, and vegetation overgrowth. Wells requiring repair and/or maintenance will be identified by field staff and scheduled for maintenance.

2.2.4.2 Water Level Measurements

A comprehensive suite of water levels will be collected from accessible wells at NASA AIGs each calendar quarter for the locations specified in Table 2. Measurements of the depth to water will be conducted per the procedures described in the FSP (Appendix A) and will be used to calculate water level elevations. Upon the eventual failure of dedicated downhole pressure transducers at wells containing the Flexible Liner Underground Technologies sampling system, an air-coupled transducer system will be set up and used to obtain approximate water levels.

2.2.4.3 Purging and Sampling

Purging and sampling of groundwater from monitoring wells will be conducted in accordance with the procedures described in the FSP (Appendix A), using low-flow/minimal drawdown sampling methods. Following the procedures in the FSP and the QAPP (Haley & Aldrich, 2010a), groundwater samples will be labeled, recorded on a chain-of-custody form, packaged for shipping and submittal to the designated laboratory, and analyzed as specified in the QAPP. Quality assurance/quality control (QA/QC) samples will be collected as specified in the QAPP addendum (Appendix B).

2.3 Waste Disposal

Waste generated during groundwater sampling activities will be contained, labeled, and disposed per the *Sitewide Waste Management Plan* (NASA, 2014b).

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SECTION 3

Sampling and Analysis Plan Elements

The elements of the NASA-specific sitewide groundwater monitoring program include the following:

- Specific procedures describing the physical process of sampling using low-flow/minimal drawdown sampling methods
- QA/QC procedures that assure the quality of data collected during the NASA-specific sitewide groundwater monitoring program activities
- Field safety procedures and personal protection monitoring

These program elements are stand-alone documents, described in the following sections, and are included as appendixes to this NASA-specific Sitewide GWQSAP.

3.1 Field Sampling Plan

The FSP provides procedures for the groundwater sampling activities including equipment and instrumentation use, sample preservation and storage, maintenance of field records, decontamination procedures, sample transport, and chain-of-custody protocols. The FSP is included as Appendix A of this document.

3.2 Quality Assurance Project Plan

The QAPP (Haley & Aldrich, 2010a) and QAPP addendum (Appendix B) outline procedures necessary to assure the quality of data collected during the NASA-specific sitewide groundwater monitoring program sampling activities at SSFL. The QAPP includes field sampling quality control procedures, sample control, and chain-of-custody procedures, analytical quality control procedures, corrective action procedures, and reporting requirements.

3.3 Health and Safety Plan

The Health and Safety Plan (HASP) for NASA SSFL (CH2M, 2014) summarizes field safety procedures and personal protection monitoring. This plan is revised routinely to incorporate changes in site conditions and/or planned fieldwork, with the most recent revision completed in August 2016. The latest version of the HASP will be followed by field staff conducting work as part of the NASA-specific sitewide groundwater monitoring program.

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SECTION 4

Analysis of Data

Data generated during the NASA-specific sitewide groundwater monitoring program will include groundwater level data, field groundwater quality parameters and laboratory analytical data. The data will be subjected to various analyses including generation of groundwater elevation contour maps, time-series plots and may include statistical analyses. The following will be performed as part of the reporting for the NASA-specific sitewide groundwater monitoring program.

4.1 Contour Maps

Groundwater level measurements will be collected quarterly from select monitoring wells (Table 2). A quarterly groundwater elevation contour map will be generated from the data, depicting the approximate equipotential surface of groundwater in the CFGW. Groundwater level data will be posted to a base map, and contour lines will be constructed by interpolating values between sample points with input and agreement from the RPs. Contour lines will be drawn manually, or by computer using contouring software, or a combination of both procedures.

The development of groundwater elevation contour maps in fractured bedrock aquifers is problematic due to the heterogeneity and anisotropy of the aquifer media. These types of aquifer systems are characterized by both fracture and matrix transmissivity, for which there is no established convention for developing groundwater elevation contour maps or determining groundwater flow directions. Therefore, groundwater elevation contours will not be used to infer groundwater flow directions or rates of groundwater movement.

4.2 Chemical of Concern Plume Maps

Validated analytical COC data from the annual groundwater sampling event will be provided in tabular form and on lateral extent maps. These maps will show the AIGs for the COCs listed in Table 1. For locations that were not sampled during the calendar year, the most recent historical result may be used to show the most representative illustration of horizontal groundwater COC extents. For these locations, the concentration and date that the sample was collected will be shown accordingly.

The extents of elevated chemical concentrations in groundwater and isoconcentration contours for each chemical will be estimated using the analytical detections during the annual monitoring event, the concentration in the most recent groundwater sample at wells that were not sampled during the calendar year, and the approximate locations of potential source areas. Aquifer system, inferred groundwater flow direction, topography, and the hydraulic influence of structural features will also be considered in the evaluation of COC extents.

4.3 Time-series Plots

Time-series plots of water level data and laboratory analytical data will be generated for the wells listed in Table 2. Time-series plots of water level data and laboratory analytical data will be generated for each COC (listed in Table 1) for each groundwater monitoring point. Time-series plots of laboratory analytical data will be limited to the wells identified for groundwater sampling in Table 2 and will not include wells designated for water level measurements only. Information plotted on the graphs will have the following characteristics:

- Water level hydrographs will be prepared by plotting water level elevations on the y-axis and time on the x-axis.
- Analyte concentrations or parameter values will be plotted on the y-axis and date will be plotted on the x-axis.

- To the extent practicable, the results for a given analyte in groundwater samples from wells associated with the same area will be shown on the same graph. For example, if possible, the wells in the ELV will be shown on a single graph per constituent.
- To the extent practicable, the graphs will depict the y-axis for a given analyte concentration at the same scale.
- If the concentration of an analyte is below the method detection limit (MDL), it will be displayed such that the viewer can determine that the analyte was not detected
- If the concentration of an analyte is below the reporting limit but above the MDL (indicated with a "J" flag in the analytical results), it will be displayed such that the viewer can determine that it was an estimated value.

4.4 Comparison to Groundwater Screening Levels

Following the annual groundwater sampling event, COC data collected from the sitewide monitoring network will be compared to the applicable GSLs (Table B-1 of Appendix B). A description of the location and magnitude of analytes exceeding the respective GSL will be documented in one (annual) groundwater monitoring report, discussed below in Section 5. Additionally, changes in concentration over time will be evaluated in one (annual) groundwater monitoring report. The overall sitewide analytical groundwater dataset will be considered in remedial decision making for SSFL.

4.5 Additional Evaluations

To support remedial alternative evaluations associated with the CMS and CMI, data collected under this NASA-specific Sitewide GWQSAP will also be evaluated for the following:

- AIG-specific COC plume stability associated with source areas and potential offsite migration (annually)
- General natural attenuation parameter trends to support future monitored natural attenuation remedial option planning (once every 2 years)

SECTION 5

Reporting

This section describes the reporting schedule for the NASA-specific sitewide groundwater monitoring program. Included are report content and the title and address of the person at DTSC to whom reports and notifications will be addressed.

5.1 Report Contents

Three quarterly reports and one annual report will be submitted for the NASA-specific sitewide groundwater monitoring program. One of the reports will present the results of sampling and analysis for COCs and other constituents in tabular and figure form as discussed in Section 4, in addition to the water level measurement data and contouring. The other reports will present the results of the quarterly water level measurement events. Report contents and submittal schedules are summarized below. Final monitoring reports will include the signature and license number of a Geologist or Engineer, registered in the State of California, who takes responsibility for the technical content of the report.

Progress reports will be prepared following the end of each monitoring event. Three quarterly progress reports will contain the following:

- Summary tables of groundwater level and groundwater quality monitoring activities
- Groundwater elevation contour maps from groundwater level data obtained during the calendar quarter
- A summary of modifications made to monitoring equipment during the sampling event, if any
- A summary of deviations from the NASA-specific Sitewide GWQSAP, if any, reasons for those deviations, and corrective measures

One annual progress report will include the following:

- An executive summary of significant findings
- The monitoring activities during the calendar year, including, but not limited to:
  - A summary of the monitoring programs and sampling activities conducted during the calendar year
  - A summary of maintenance inspections of monitored wells
  - A summary of modifications made to monitoring equipment during the calendar year, if any
  - A summary of deviations from the NASA-specific Sitewide GWQSAP, if any, reasons for those deviations, and corrective measures
- A summary and interpretation of the monitoring program results during the previous calendar year, including, but not limited to the following:
  - Groundwater level data and groundwater elevation map
  - Results of laboratory analyses presented in summary tables. Laboratory analytical reports and sample custody documents will be provided electronically. Upon request, hard copies of these documents will be provided to DTSC, under separate cover
  - Summary of the results of QA/QC sampling and analysis. The report will provide an assessment of data quality, including accuracy, precision, and completeness. The report will indicate proposed corrective measures if necessary (such as resampling)

- Concentrations of COCs in groundwater samples from sitewide monitoring wells, as well as the estimated areal extent of COCs above the applicable GSL, will be presented on maps
- Summary of the results of plume stability evaluations, if any, for COC plumes that have a potential for offsite migration
- Time-series graphs showing concentrations of COCs during the monitoring period, and a discussion of evident trends
- Summary tables of constituent concentrations that exceed the GSLs
- Significant events that may influence the occurrence, movement, or quality of groundwater, including precipitation events, and importation of water
- Summary table and brief discussion of bi-annual natural attenuation data (to be included in reports for odd-numbered years)

Each report will include a section that tracks unresolved issues and/or follow-up work (such as verification sampling of apparently significant evidence of a release; repair or replacement of wells or equipment).

5.2 Submittal Dates

Each monitoring report will be submitted within 3 months of the end of each quarter in which the monitoring event was conducted.

5.3 DTSC Contacts

Unless otherwise specifically stated elsewhere in this NASA-specific Sitewide GWQSAP, NASA will submit required notifications and/or report submittals to DTSC at the following address:

Department of Toxic Substances Control
Attn: SSFL Project Director
8800 Cal Center Drive
Sacramento, CA 95824

SECTION 6

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Tables

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TABLE 1

Groundwater Sampling Parameters and Analytical Method Information

NASA-specific Sitewide Groundwater Quality Sampling and Analysis Plan, SSFL, Ventura, California

Groundwater Sampling Plan[a]	Method	Analyte
Field Parameters (Annual)	Water Quality Meter	Dissolved Oxygen Oxidation-Reduction Potential pH Temperature Specific Conductance Turbidity
COCs (Annual)	EPA 1625	n-Nitrosodimethylamine
	SW6010B/6020	Cadmium, total and dissolved Lead, total and dissolved
	SW8260B	cis-1,2-Dichloroethene trans-1,2-Dichloroethene Trichloroethene Vinyl Chloride
	SW8260B-SIM	1,2,3-Trichloropropane 1,4-Dioxane
	SW8315A	Formaldehyde
Natural Attenuation Parameters[b] (Biannual)	EPA300.0	Nitrate Nitrite Sulfate
	RSK-175	Ethane Ethene Methane
	SM3500-Fe-D	Iron (II)
	SM4500-SD	Sulfide, total
	SW6010B/6020	Manganese, dissolved
	SM5310B	Total Organic Carbon

[a] Groundwater sampling will occur during the first quarter of the calendar year.

[b] The collection of groundwater samples for natural attenuation parameter analysis will occur during odd-numbered years.

AIG = Area of Impacted Groundwater

COC = chemical of concern

EPA = U.S. Environmental Protection Agency

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TABLE 2

Proposed Monitoring Network and Sampling Program

NASA-specific Sitewide Groundwater Quality Sampling and Analysis Plan, SSFL, Ventura, California

AIG	Station ID	Sample ID	Groundwater Sampling Plan[a] (see Table 3 for analytes and methods)		Water Level Measurement Frequency		Sentinel Monitoring Well	Rationale
			COCs (Annual)	NA Parameters[b] (Bi-annual)	Annual[c]	Quarterly		
Alfa/Bravo	C-5-1				X			To provide COC and NA data within the Coca Area source area along plume centerline to monitor plume stability and support remedial action decisions; a subset of ports were chosen for groundwater sampling to span the depth of the vertical profile of the plume. Water levels will be collected at all ports with transducers during sampling only (not a key location for groundwater contouring).
	C-5-2	C5GW02Saaa	X	X	X			
	C-5-3				X			
	C-5-4	C5GW04Saaa	X	X	X			
	C-5-5				X			
	C-5-6	C5GW06Saaa	X	X	X			
	HAR-05					X		Key location for groundwater elevation contouring but outside of a COC plume centerline or edge.
	HAR-06	HAR06GWSaaa	X	X		X		Downgradient well to HAR-21 source area well. Sampled to monitor COC concentration trends downgradient of source area, plume stability, and evaluate potential NA.
	HAR-11	HAR11GWSaaa	X	X		X		Downgradient well to Alfa Area NSGW source areas. Sampled to monitor COC concentration trends downgradient of source areas, plume stability, and evaluate potential NA.
	HAR-14					X		Key location for groundwater elevation contouring but outside of a COC plume centerline or edge.
	HAR-19					X		Key location for groundwater elevation contouring within the Bravo Area COC plume. Consistently above screening levels in the central portion of the Bravo Area Plume.
	HAR-21	HAR21GWSaaa	X	X		X		Alfa/Bravo Skim Pond source area well. Sampled to monitor source area COC concentration trends, plume stability, and evaluate potential NA.
	HAR-31					X		Key location for groundwater elevation contouring but outside of a COC plume centerline or edge.
	ND-132-1	ND132GW01Saaa	X	X	X			Bravo Area plume monitoring well where highest COC concentrations are in Port 1. Sample a representative subset of ports over the well depth to monitor COC concentration trends with depth, plume stability, and evaluate potential NA. Water levels will be monitored in all ports to evaluate vertical gradients during sampling only (not a key location for groundwater contouring).
	ND-132-2				X			
	ND-132-3				X			
	ND-132-4	ND132GW04Saaa	X	X	X			
	ND-132-5	ND132GW05Saaa	X	X	X			
	ND-133-1	ND133GW01Saaa	X	X		X		Monitoring well between Alfa and Bravo Areas. Sample a representative subset of ports over the well depth to monitor COC concentration trends with depth, plume stability, and evaluate potential NA. Water levels will be monitored in all ports to evaluate vertical gradients.
	ND-133-2					X		
	ND-133-3	ND133GW03Saaa	X	X		X		
	ND-133-4	ND133GW04Saaa	X	X		X		
	ND-134-1	ND134GW01Saaa	X		X			Monitoring well downgradient of Bravo Area source area. Sample the top and bottom ports to representatively monitor COC concentration trends, plume stability, and evaluate potential NA. Ports 1 and 2 generally have similar concentrations to each other, with Port 1 generally having higher COC concentrations. Ports 3 and 4 generally have similar concentrations to each other, with Port 4 generally having higher COC concentrations. Water levels will be monitored in all ports to evaluate vertical gradients during sampling only (not a key location for groundwater contouring).
	ND-134-2				X			
	ND-134-3				X			
	ND-134-4	ND134GW04Saaa	X		X			
	ND-135-1	ND135GW01Saaa	X	X		X		Monitoring well downgradient of the Bravo Test Stand source area. Sample three representative ports to monitor COC concentration trends, plume stability, and evaluate potential NA. Port 1 generally has the highest COC concentrations. Sample Ports 4 and 6 to provide representative data to show lower COC concentrations with depth. Water levels will be monitored in all ports to evaluate vertical gradients.
	ND-135-2					X		
	ND-135-3					X		
	ND-135-4	ND135GW04Saaa	X	X		X		
	ND-135-5					X		
	ND-135-6	ND135GW06Saaa	X	X		X		
	ND-136-1	ND136GW01Saaa	X	X	X			Alfa Area source area well. Sample the top and bottom ports to representatively monitor COC concentration trends, plume stability, and evaluate potential NA. Port 1 generally has the highest COC concentrations. Port 4 provides a representative point to show lower COC concentrations at depth. Water levels will be monitored in all ports to evaluate vertical gradients during sampling only (not a key location for groundwater contouring).
	ND-136-2				X			
	ND-136-3				X			
	ND-136-4	ND136GW04Saaa	X	X	X			
	ND-137A					X		Measure the water level only to evaluate vertical gradient (location nondetect for COCs).

TABLE 2

Proposed Monitoring Network and Sampling Program

NASA-specific Sitewide Groundwater Quality Sampling and Analysis Plan, SSFL, Ventura, California

AIG	Station ID	Sample ID	Groundwater Sampling Plan[a] (see Table 3 for analytes and methods)		Water Level Measurement Frequency		Sentinel Monitoring Well	Rationale
			COCs (Annual)	NA Parameters[b] (Bi-annual)	Annual[c]	Quarterly		
Alfa/Bravo cont.	ND-137B	ND137BGWSaaa	X	X		X		Downgradient plume centerline well from Alfa Area source area. Sampled to monitor source area COC concentration trends, plume stability, and evaluate potential NA.
	PZ-154					X		Typically dry well. Water level will be checked to verify dryness (Alfa Area source area NSGW well).
	PZ-155					X		Typically dry well. Water level will be checked to verify dryness (deepest Bravo Area NSGW well).
	PZ-158					X		Typically dry well. Water level will be checked to verify dryness (deepest SPA NSGW well).
	RD-04	RD04GWSaaa	X			X		Cross gradient well to Bravo Area source area. Sampled to monitor source area COC concentration trends and plume stability.
	RD-49A	RD49AGWSaaa	X	X		X		Downgradient plume centerline well from Alfa Area source area with the highest COC concentrations of the well pair. Sampled to monitor source area COC concentration trends, plume stability, and evaluate potential NA.
	RD-49B	RD49BGWSaaa	X			X		Deeper well, co-located with RD-49A, with lower COC concentrations. Sampled to monitor COC concentration trends and plume stability deeper within the plume.
	RD-49C					X		Lowest COC concentrations in well pair. Measure just the water level to evaluate vertical gradients.
	RS-34					X		Key location for groundwater elevation contouring but outside of a COC plume centerline or edge.
	WS-09	WS09GWSaaa	X	X		X		Bravo Test Stand source area well. Sampled to monitor source area COC concentration trends, plume stability, and evaluate potential NA.
B204/ELV	C-7-1	C7GW01Saaa	X	X		X		ELV Catchment Pond source area well. Sampled to monitor source area COC concentration trends, plume stability, and evaluate potential NA. Concentrations vary with depth so all saturated intervals will be sampled. Water levels will be monitored in all ports to evaluate vertical gradients.
	C-7-2	C7GW02Saaa	X	X		X		
	C-7-3	C7GW03Saaa	X	X		X		
	ES-22					X		Typically dry well. Water level will be checked to verify dryness (representative of shallow AP/STP area wells).
	HAR-22					X		Key location for groundwater elevation contouring but outside of a COC plume centerline or edge.
	ND-122-1					X		Building 204 Area COC plume centerline well. Sampled to monitor COC concentration trends, plume stability, and evaluate potential NA. COC concentrations only detected at depth so Ports 2 and 3 will be sampled. Water levels will be monitored in all ports to evaluate vertical gradients.
	ND-122-2	ND122GW02Saaa	X			X		
	ND-122-3	ND122GW03Saaa	X			X		
	ND-123-1	ND123GW01Saaa	X	X		X	X	Sentinel monitoring well down gradient of ELV source areas (low detections of COCs to date). Ports 3 and 4 nondetect for COCs so Port 4 excluded from sampling. Water levels will be monitored in all ports to evaluate vertical gradients.
	ND-123-2	ND123GW02Saaa	X	X		X	X	
	ND-123-3	ND123GW03Saaa	X	X		X	X	
	ND-123-4					X		
	ND-124-1					X		Sentinel monitoring well for COCs downgradient of Building 204 Area source area (at leading edge of 1,4-dioxane plume as well). Port 4 is only port with sufficient water to sample. Water levels will be monitored in all ports to evaluate dryness or vertical gradients.
	ND-124-2					X		
	ND-124-3					X		
	ND-124-4	ND124GW04Saaa	X			X	X	
	ND-125-1	ND125GW01Saaa	X	X		X		ELV COC plume centerline well. Sampled to monitor COC concentration trends, plume stability, and evaluate potential NA. COC concentrations similar with depth so every-other port will be sampled. Water levels will be monitored in all available ports to evaluate vertical gradients (Ports 2 and 5 do not have transducers).
	ND-125-3	ND125GW03Saaa	X	X		X		
	ND-125-4					X		
	ND-125-5	ND125GW05Saaa	X	X				
	ND-126	ND126GWSaaa	X			X	X	Sentinel monitoring well down gradient of AP/STP source areas (low detections of COCs to date).
	ND-127	ND127GWSaaa	X			X	X	Sentinel monitoring well down gradient of ELV source areas (nondetect for COCs to date).
	ND-128-1	ND128GW01Saaa	X	X		X		Building 204 COC plume centerline well. Sampled to monitor COC concentration trends, plume stability, and evaluate potential NA. COC concentrations vary with depth so all saturated ports will be sampled. Water levels will be monitored in all ports to evaluate vertical gradients.
	ND-128-2	ND128GW02Saaa	X	X		X		
	ND-128-3	ND128GW03Saaa	X	X		X		
	NS-42A					X		Shallow well paired with NS-42B. Is typically dry. Water level will be checked to verify dryness or provide vertical gradient information.

TABLE 2

Proposed Monitoring Network and Sampling Program

NASA-specific Sitewide Groundwater Quality Sampling and Analysis Plan, SSFL, Ventura, California

AIG	Station ID	Sample ID	Groundwater Sampling Plan[a] (see Table 3 for analytes and methods)		Water Level Measurement Frequency		Sentinel Monitoring Well	Rationale
			COCs (Annual)	NA Parameters[b] (Bi-annual)	Annual[c]	Quarterly		
B204/ELV cont.	NS-42B	NS42BGWSaaa	X	X		X		ELV Catchment Pond source area well co-located with C-7. Sampled to monitor source area COC concentration trends, plume stability, and evaluate potential NA.
	PZ-001B					X		Plume centerline well associated with AP/STP source areas. Shallow ports typically dry so will sample two deepest ports. Water levels will be monitored in all ports to evaluate dryness or vertical gradients.
	PZ-001C					X		
	PZ-001D					X		
	PZ-001E	PZ001EGWSaaa	X	X		X		
	PZ-001F	PZ001FGWSaaa	X	X		X		
	PZ-007C					X		Plume centerline well associated with AP/STP source areas. Shallow ports typically dry so will sample deepest port. Water levels will be monitored in all ports to evaluate dryness or vertical gradients.
	PZ-007D					X		
	PZ-007E					X		
	PZ-007F					X		
	PZ-007G	PZ007GGWSaaa	X	X		X		
	PZ-139	PZ139GWSaaa	X	X		X		NSGW plume monitoring location in ELV. Sampled to monitor COC concentration trends, plume stability, and evaluate potential NA.
	PZ-140					X		NSGW plume monitoring location in ELV. Sampled to monitor COC concentration trends, plume stability, and evaluate potential NA.
	PZ-141	PZ141GWSaaa	X	X		X		NSGW source area monitoring location in ELV. Sampled to monitor COC concentration trends, plume stability, and evaluate potential NA.
	PZ-147					X		Typically dry well. Water level will be checked to verify dryness (AP/STP source area well).
	RD-09	RD09GWSaaa	X	X		X		AP/STP source area well. Sampled to monitor source area COC concentration trends, plume stability, and evaluate potential NA.
	RD-26					X		Key location for groundwater elevation contouring but outside of a COC plume centerline or edge.
	RD-56A-1					X		Building 204 COC plume centerline well and key well to monitoring for potential off-site migration. Sampled to monitor COC concentration trends, plume stability, and evaluate potential NA. Port 1 typically dry. Water levels will be monitored in all ports to evaluate dryness or vertical gradients.
	RD-56A-2	RD56AGW02Saaa	X	X		X		
	RD-56A-3	RD56AGW03Saaa	X	X		X		
	RD-56B	RD56BGWSaaa	X			X	X	Building 204 COC plume sentinel well beneath ELV Member. Sampled to monitor COC concentration trends co-located with RD-56A (COC concentrations at this depth typically below GSLs).
	RD-68A					X		COC sentinel monitoring location at base of slope downgradient of B204/ELV AIG to verify offsite nondetect COC concentrations.
	RD-68B					X		
	RD-70					X		Key location for groundwater elevation contouring but outside of a COC plume centerline or edge.
	SP-29A				X			Sentinel monitoring for offsite COC migration. Seep well cluster location with previous low 1,4-dioxane detection that will be monitored. SP-29A is typically dry. Water levels will only be measured associated with sampling because of difficult well access.
	SP-29B	SP29BGWSaaa	X		X		X	
	SP-29C	SP29CGWSaaa	X		X		X	
	SP-30A				X			Sentinel monitoring for offsite COC migration. Seep well cluster location with previous low TCE detection that will be monitored. SP-30A is typically dry. Will sample two depths, including the deepest point for representative monitoring. Water levels will only be measured associated with sampling because of difficult well access.
	SP-30B	SP30BGWSaaa	X		X		X	
	SP-30C				X			
	SP-30D	SP30DGWSaaa	X		X		X	
	SP-33A	SP33GWSaaa	X		X		X	Sentinel monitoring for offsite COC migration. Seep well cluster has been nondetect for COCs to date. Will sample the shallowest and deepest points for representative monitoring. Water levels will only be measured associated with sampling because of difficult well access.
	SP-33B				X			
	SP-33C	SP33CGWSaaa	X		X		X	
Coca/Delta	C-6	C6GWSaaa	X	X		X		Coca/Delta Skim Pond source area well. Sampled to monitor source area COC concentration trends, plume stability, and evaluate potential NA in recently completed deep well in this corehole.
	FDP-882	FDP882GWSaaa	X			X (note if contains flowing/st		Seep south of Area II in southern drainage that has recently contained water to allow sampling. Sample COCs to monitor potential surface water discharges.
	HAR-07	HAR07GWSaaa	X	X		X		Coca/Delta Skim Pond source area well. Sampled to monitor source area COC concentration trends, plume stability, and evaluate potential NA in shallower depth than C-6.

TABLE 2

Proposed Monitoring Network and Sampling Program

NASA-specific Sitewide Groundwater Quality Sampling and Analysis Plan, SSFL, Ventura, California

AIG	Station ID	Sample ID	Groundwater Sampling Plan[a] (see Table 3 for analytes and methods)		Water Level Measurement Frequency		Sentinel Monitoring Well	Rationale
			COCs (Annual)	NA Parameters[b] (Bi-annual)	Annual[c]	Quarterly		
Coca/Delta cont.	HAR-08					X		Key location for groundwater elevation contouring within the Delta area COC plume. Groundwater analytical information in the area is covered by sampling HAR-07.
	HAR-17	HAR17GWSaaa	X	X	X			Delta area plume well to monitor COC concentration trends, plume stability, and evaluate potential NA in a location downgradient of Area III plume contributions into Area II. Water level is not key for sitewide groundwater elevation contours so water level will only be measured during sampling events.
	HAR-27					X		Key location for groundwater elevation contouring within the Delta area COC plume. Groundwater analytical information in the area is covered by sampling HAR-07.
	HAR-29					X		Key location for groundwater elevation contouring within the Delta area COC plume. Groundwater analytical information in the area is covered by sampling HAR-07.
	ND-113-1	ND113GW01Saaa	X	X		X		Coca area COC plume centerline well. Sampled to monitor COC concentration trends, plume stability, and evaluate potential NA. COC concentrations vary with depth so all ports will be sampled. Water levels will be monitored to evaluate vertical gradients.
	ND-113-2	ND113GW02Saaa	X	X		X		
	ND-113-3	ND113GW03Saaa	X	X		X		
	ND-114-1	ND114GW01Saaa	X	X		X		Coca area COC plume centerline well. Sampled to monitor COC concentration trends, plume stability, and evaluate potential NA. COC concentrations similar with depth so a subset of ports will be sampled. Water levels will be monitored in available ports to evaluate vertical gradients (no transducer in Port 2).
	ND-114-3					X		
	ND-114-4	ND114GW04Saaa	X	X		X		
	ND-115-1					X		R-2 Ponds source area well. Sampled to monitor source area COC concentration trends, plume stability, and evaluate potential NA. Port 1 has COCs below GSLs so is excluded from sampling. Water levels will be monitored in available ports to evaluate vertical gradients (Port 4 does not have a transducer).
	ND-115-2	ND115GW02Saaa	X	X		X		
	ND-115-3	ND115GW03Saaa	X	X		X		
	ND-115-4	ND115GW04Saaa	X	X				
	ND-116-1	ND116GW01Saaa	X				X	Sentinel multiwell to monitor COC concentration trends and plume stability (1,4-dioxane is the only COC detected above GSLs in this well). COC concentrations are similar with depth so the top and bottom ports will be sampled. Water levels will be monitored in available ports to evaluate vertical gradients (Ports 1 and 3 do not have transducers).
	ND-116-2					X		
	ND-116-4					X		
	ND-116-6	ND116GW06Saaa	X			X	X	
	ND-117					X		Key location for groundwater elevation contouring but outside of a COC plume centerline or edge.
	PZ-004A					X		Typically dry well. Water level will be checked to verify dryness (Delta Area source area NSGW well).
	PZ-047					X		Typically dry well. Water level will be checked to verify dryness (Coca Area source area NSGW well).
	RD-05A					X		Well cluster is a key location for groundwater elevation contouring and vertical gradient information but outside of a COC plume centerline or edge.
	RD-05B					X		
	RD-05C					X		
	RD-06	RD06GWSaaa	X		X		X	Sentinel monitoring well downgradient of the Area II/Area III COC plumes. Sampled to monitor for potential plume expansion and early warning of offsite migration (which is not expected). Water level is not key for sitewide groundwater elevation contours so water level will only be tagged associated with sampling.
	RD-40					X		Key location for groundwater elevation contouring but outside of a COC plume.
	RD-41A					X		Leading edge Coca Area plume monitoring well. RD-41B has the highest COC concentrations and will be monitored for COC concentration trends, plume stability, and to evaluate potential NA. Water levels will be measured at wells RD-41A and RD-41C to evaluate vertical gradients.
	RD-41B	RD41BGWSaaa	X	X		X		
	RD-41C					X		
	RD-79	RD79GWSaaa	X	X		X		Key location for groundwater elevation contouring within the Coca Area plume.
	RS-10					X		Typically dry well. Water level will be checked to verify dryness (Coca/Delta Area NSGW well).

TABLE 2

Proposed Monitoring Network and Sampling Program

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AIG	Station ID	Sample ID	Groundwater Sampling Plan[a] (see Table 3 for analytes and methods)		Water Level Measurement Frequency		Sentinel Monitoring Well	Rationale
			COCs (Annual)	NA Parameters[b] (Bi-annual)	Annual[c]	Quarterly		
Coca/Delta cont.	SP-881A				X			Seep well cluster within the downgradient portion of the Area II/Area III COC plume. Sampled to monitor COC concentration trends, plume stability, and evaluate potential NA in the southern drainage. Water level is not key for sitewide groundwater elevation contours so water level will only be tagged associated with sampling.
	SP-881B	SP881BGWSaaa	X	X	X			
	SP-881C	SP881CGWSaaa	X	X	X			
	SP-881D				X			
	SP-881G	SP881GGWSaaa	X	X	X			
	SP-882A	SP882AGWSaaa	X		X		X	Sentinel seep well cluster downgradient of the Area II/Area III COC plumes. Sampled to monitor for potential plume expansion and early warning of offsite migration (which is not expected). Water level is not key for sitewide groundwater elevation contours so water level will only be tagged associated with sampling.
	SP-882B	SP882BGWSaaa	X		X		X	
	SP-882C	SP882CGWSaaa	X		X		X	
	SP-882D				X			
	SP-882G	SP882GGWSaaa	X		X		X	
	SP-890A				X			Seep well cluster within the downgradient portion of the Area II/Area III COC plume. Sampled to monitor COC concentration trends, plume stability, and evaluate potential NA in the southern drainage. Water level is not key for sitewide groundwater elevation contours so water level will only be tagged associated with sampling.
	SP-890B				X			
	SP-890C	SP890CGWSaaa	X	X	X			
	SP-890D				X			
	SP-890G	SP890GGWSaaa	X	X	X			
	WS-09A	WS09AGWSaaa	X	X		X		Deep well either within or outside the COC plume. Sampled to monitor source area COC concentration trends, plume stability, and evaluate potential NA in an area of potential plume variability.
Former LOX Plant	ND-111-1	ND111GW01Saaa	X			X	X	Sentinel monitoring well for COCs downgradient of LOX source area. Not along main plume centerline so NA parameters are not needed. COC concentrations vary with depth so all saturated, accessible ports will be sampled. Water levels will be monitored in all ports to evaluate vertical gradients.
	ND-111-2	ND111GW02Saaa	X			X	X	
	ND-111-3	ND111GW03Saaa	X			X	X	
	ND-112-1					X		LOX source area well. Sampled to monitor source area COC concentration trends, plume stability, and evaluate potential NA. Concentrations have been similar with depth so the top and bottom saturated intervals will be sampled. Water levels will be monitored in all ports to evaluate vertical gradients.
	ND-112-2	ND112GW02Saaa	X	X		X		
	ND-112-3					X		
	ND-112-4	ND112GW04Saaa	X	X		X		
	RD-52A	RD52AGWSaaa	X	X	X			COC plume centerline well. Sampled to monitor COC concentration trends, plume stability, and evaluate potential NA. Boeing's sampling of RD-52B and RD-52C will cover COC needs at these wells. Boeing is expected to measure water levels at all three wells quarterly.
	RD-69					X		Key location for groundwater elevation contouring but outside of a COC plume centerline or edge.
	RD-80					X		Key location for groundwater elevation contouring but outside of COC plume centerline.
	RD-81-1	RD81GW01Saaa	X	X		X		COC plume centerline well. Sampled to monitor COC concentration trends, plume stability, and evaluate potential NA. Ports 3 and 4 were nondetect for COCs so will exclude Port 4 from sampling. Water levels will be monitored in all ports to evaluate vertical gradients.
	RD-81-2	RD81GW02Saaa	X	X		X		
	RD-81-3	RD81GW03Saaa	X	X		X		
	RD-81-4					X		
	WS-04A					X		Key location for groundwater elevation contouring but outside of a COC plume centerline or edge.
	WS-12	WS12GWSaaa	X	X		X		COC plume centerline well. Sampled to monitor COC concentration trends, plume stability, and evaluate potential NA. Sample will be collected at the depth of the highest previous depth-discrete sample location (see Table 3).
	WS-13	WS13GWSaaa	X			X	X	Downgradient sentinel monitoring well for the LOX COC plumes. Sample will be collected at an elevation similar to the WS-12 sample (see Table 3).

[a] Groundwater sampling will occur during the first quarter of the calendar year.

[b] The collection of groundwater samples for NA parameter analysis will occur during odd-numbered years.

[c] Wells marked for annual monitoring will only be gauged during the quarter they are sampled because they are not critical to the production of quarterly groundwater elevation contour maps.

aaa = sample number; Increases with each round of sampling

AP/STP = Ash Pile/Sewage Treatment Plant

AIG = Area of Impacted Groundwater

B204 = Building 204

COC = chemical of concern

ELV = Expendable Launch Vehicle

GSL = groundwater screening level

ID = identification number

LOX = liquid oxygen

NA = natural attenuation

NSGW = near-surface groundwater

SPA = Storable Propellant Area

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TABLE 3

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NASA-specific Sitewide Groundwater Quality Sampling and Analysis Plan, SSFL, Ventura, California

AIG	Well ID	Type	Owner	Well Diameter (inches)	Top of Casing Elevation (ft msl)	Ground Surface Elevation (ft msl)	Screen or Open Interval Top (ft bgs)	Screen or Open Interval Bottom (ft bgs)	Total Well Depth (ft bgs)	Pump Type	Pump Inlet Depth (if dedicated) (ft BTOC)	Minimum Portable Pump Inlet Target Depth[a] (ft BTOC)
Alfa/Bravo	C-5	Multilevel Monitoring Well	NASA	5 / 3.8 / 3.3	1899.25	1898.26	45	800	800	FLUTe ports	--	--
	C-5-1	FLUTe Port		--	--	--	290	305	--	--	--	--
	C-5-2	FLUTe Port		--	--	--	365	380	--	--	--	--
	C-5-3	FLUTe Port		--	--	--	474	482	--	--	--	--
	C-5-4	FLUTe Port		--	--	--	606	621	--	--	--	--
	C-5-5	FLUTe Port		--	--	--	630	635	--	--	--	--
	C-5-6	FLUTe Port		--	--	--	780	795	--	--	--	--
	HAR-05	Monitoring Well	NASA	8	1812.72	1811.3	30	180	180	--	--	--
	HAR-06	Monitoring Well	NASA	8	1815.19	1814.02	30	160	160	Portable Low-Flow Bladder	--	96.40
	HAR-11	Monitoring Well	NASA	4	1827.78	1828	11.2	31	31	Bladder (QED Well Wizard T1200M)	30.8	--
	HAR-14	Monitoring Well	NASA	4	1796.91	1795.22	11.8	40	40	--	--	--
	HAR-19	Monitoring Well	NASA	8	1833.28	1831.51	30	220	220	--	--	--
	HAR-21	Monitoring Well	NASA	8	1821.42	1820.34	30	130	130	Bladder (QED Well Wizard T1200M)	43 59.5 76 92.5 109	--
	HAR-31	Monitoring Well	NASA	4	1812.32	1810.82	22	40	40	--	--	--
	ND-132	Multilevel Monitoring Well	NASA	6.5 / 5 / 2	1848.42	1848.96	30	650	650	FLUTe ports	--	--
	ND-132-1	FLUTe Port		--	--	--	275	290	--	--	--	--
	ND-132-2	FLUTe Port		--	--	--	383	398	--	--	--	--
	ND-132-3	FLUTe Port		--	--	--	415	430	--	--	--	--
	ND-132-4	FLUTe Port		--	--	--	470	485	--	--	--	--
	ND-132-5	FLUTe Port		--	--	--	615	632	--	--	--	--
	ND-133	Multilevel Monitoring Well	NASA	6.25	1866.41	1866.96	45	600	600	FLUTe ports	--	--
	ND-133-1	FLUTe Port		--	--	--	286	301	--	--	--	--
	ND-133-2	FLUTe Port		--	--	--	343	358	--	--	--	--
	ND-133-3	FLUTe Port		--	--	--	467	482	--	--	--	--
	ND-133-4	FLUTe Port		--	--	--	580	590	--	--	--	--
	ND-134	Multilevel Monitoring Well	NASA	3.782	1881.59	1882.08	12.6	452	452	FLUTe ports	--	--
	ND-134-1	FLUTe Port		--	--	--	275.5	291.5	--	--	--	--
	ND-134-2	FLUTe Port		--	--	--	300	310	--	--	--	--
	ND-134-3	FLUTe Port		--	--	--	392	407	--	--	--	--
	ND-134-4	FLUTe Port		--	--	--	433	448	--	--	--	--
	ND-135	Multilevel Monitoring Well	NASA	3.782	1832.8	1829.56	26	550	550	FLUTe ports	--	--
	ND-135-1	FLUTe Port		--	--	--	198	213	--	--	--	--
	ND-135-2	FLUTe Port		--	--	--	240	257	--	--	--	--
	ND-135-3	FLUTe Port		--	--	--	330	345	--	--	--	--
	ND-135-4	FLUTe Port		--	--	--	436	451	--	--	--	--
	ND-135-5	FLUTe Port		--	--	--	498	513	--	--	--	--
	ND-135-6	FLUTe Port		--	--	--	534	549	--	--	--	--
	ND-136	Multilevel Monitoring Well	NASA	3.782	1899.6	1898.58	48.2	553.5	553.5	FLUTe ports	--	--
	ND-136-1	FLUTe Port		--	--	--	307	322	--	--	--	--
	ND-136-2	FLUTe Port		--	--	--	376	386	--	--	--	--
	ND-136-3	FLUTe Port		--	--	--	445	460	--	--	--	--
	ND-136-4	FLUTe Port		--	--	--	515	530	--	--	--	--

TABLE 3

Summary of Construction Data for NASA Sitewide Groundwater Monitoring Program Wells

NASA-specific Sitewide Groundwater Quality Sampling and Analysis Plan, SSFL, Ventura, California

AIG	Well ID	Type	Owner	Well Diameter (inches)	Top of Casing Elevation (ft msl)	Ground Surface Elevation (ft msl)	Screen or Open Interval Top (ft bgs)	Screen or Open Interval Bottom (ft bgs)	Total Well Depth (ft bgs)	Pump Type	Pump Inlet Depth (if dedicated) (ft BTOC)	Minimum Portable Pump Inlet Target Depth[a] (ft BTOC)
Alfa/Bravo cont.	ND-137A	Monitoring Well	NASA	2	1911.03	1908.1	110	150	150	Portable Low-Flow Bladder	--	132.90
	ND-137B	Monitoring Well	NASA	2	1911.76	1908.74	560	600	600	Bladder (QED Well Wizard T1102)	575	--
	PZ-154	Piezometer	NASA	2	1902.3	1899.9	50	60	61	--	--	--
	PZ-155	Piezometer	NASA	2	1831.9	1829.7	51.47	61.47	62	--	--	--
	PZ-158	Piezometer	NASA	2	1797.4	1795.4	12.24	22.24	22.74	--	--	--
	RD-04	Extraction Well	NASA	8.625	1883.93	1882.76	27	496	496	Grundfos Model 10S30-34	300	--
	RD-49A	Monitoring Well	NASA	6.25	1867.28	1866.96	18.5	50	50	Bladder (QED Well Wizard T1200M)	38	--
	RD-49B	Monitoring Well	NASA	5 7/8 to 11 7/8	1868.11	1867.2	250	298	298	ES-VFD (Grundfos RediFlo4-5E8)	274	--
	RD-49C	Monitoring Well	NASA	6 1/4 to 11 7/8	1869.63	1868.9	491	558	558	--	--	--
	RS-34	Monitoring Well	NASA	4	1808.87	1807.11	14.5	34.5	35	--	--	--
	WS-09	Extraction Well	NASA	10 to 15	1883.95	1882.26	17	800	800	Grundfos Model 10S30-34	300	--
B204/ELV	C-7	Multilevel Monitoring Well	NASA	5	1831.51	1830.16	39.4	419.1	419.1	FLUTe ports	--	--
	C-7-1	FLUTe Port		--	1831.54	1830.16	190	205	--	--	--	--
	C-7-2	FLUTe Port		--	1831.57	1830.16	275	290	--	--	--	--
	C-7-3	FLUTe Port		--	1831.63	1830.16	374	389	--	--	--	--
	ES-22	Extraction Well		6	1770.93	1769.9	17.5	35.5	35.5	--	--	--
	HAR-22	Monitoring Well		8	1816.62	1815.7	30	90	90	--	--	--
	ND-122	Multilevel Monitoring Well	NASA	3.78	1804.58	1801.95	29	345.9	345.9	FLUTe ports	--	--
	ND-122-1	FLUTe Port		--	1804.58	1801.95	133	148	--	--	--	--
	ND-122-2	FLUTe Port		--	1804.6	1801.95	237	252	--	--	--	--
	ND-122-3	FLUTe Port		--	1804.64	1801.95	303	318	--	--	--	--
	ND-123	Multilevel Monitoring Well	NASA	3.5	1855.36	1856.79	19.1	475	475	FLUTe ports	--	--
	ND-123-1	FLUTe Port		--	1855.5	1856.79	241	256	--	--	--	--
	ND-123-2	FLUTe Port		--	1855.54	1856.79	284	299	--	--	--	--
	ND-123-3	FLUTe Port		--	1855.42	1856.79	320	335	--	--	--	--
	ND-123-4	FLUTe Port		--	1855.4	1856.79	464	474	--	--	--	--
	ND-124	Multilevel Monitoring Well	NASA	3.78	1785.32	1782.89	20	602.7	602.7	FLUTe ports	--	--
	ND-124-1	FLUTe Port		--	1785.43	1782.89	318	333	--	--	--	--
	ND-124-2	FLUTe Port		--	1785.44	1782.89	413.5	430.5	--	--	--	--
	ND-124-3	FLUTe Port		--	1785.43	1782.89	492	507	--	--	--	--
	ND-124-4	FLUTe Port		--	1785.47	1782.89	539	554	--	--	--	--
	ND-125	Multilevel Monitoring Well	NASA	3.5	1855.96	1856.77	19	400	400	FLUTe ports	--	--
	ND-125-1	FLUTe Port		--	--	--	190	205	--	--	--	--
	ND-125-2	FLUTe Port		--	--	--	230	245	--	--	--	--
	ND-125-3	FLUTe Port		--	--	--	260	275	--	--	--	--
	ND-125-4	FLUTe Port		--	--	--	340	355	--	--	--	--
	ND-125-5	FLUTe Port		--	--	--	375	385	--	--	--	--
	ND-126	Monitoring Well	NASA	6	1743.26	1740.57	20	205	205	Portable Low-Flow Bladder	--	115.19
	ND-127	Monitoring Well	NASA	3.78	1825.76	1825.71	29.8	300	300	Portable High-Pressure Bladder	--	164.33
	ND-128	Multilevel Monitoring Well	NASA	3.78	1879.85	1880.29	20	398.7	398.7	FLUTe ports	--	--
	ND-128-1	FLUTe Port		--	--	--	166	181	--	--	--	--
	ND-128-2	FLUTe Port		--	--	--	243	259	--	--	--	--
	ND-128-3	FLUTe Port		--	--	--	375	390	--	--	--	--
	NS-42A	Nested PVC Port	NASA	2	1829.61	1829.97	88	108	108	--	--	--
	NS-42B	Nested PVC Port	NASA	2	1829.61	1830.11	133	148	148	Portable Low-Flow Bladder	--	140

TABLE 3

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AIG	Well ID	Type	Owner	Well Diameter (inches)	Top of Casing Elevation (ft msl)	Ground Surface Elevation (ft msl)	Screen or Open Interval Top (ft bgs)	Screen or Open Interval Bottom (ft bgs)	Total Well Depth (ft bgs)	Pump Type	Pump Inlet Depth (if dedicated) (ft BTOC)	Minimum Portable Pump Inlet Target Depth[a] (ft BTOC)
B204/ELV cont.	PZ-001	Multilevel Piezometer	NASA	--	1768.5	1766	--	--	60	--	--	--
	PZ-001A	Segmented PVC Port		< 0.6	1768.5	1766	5.75	6.25	6.25	--	--	--
	PZ-001B	Segmented PVC Port		< 0.6	1768.5	1766	17.75	18.25	18.25	--	--	--
	PZ-001C	Segmented PVC Port		< 0.6	1768.5	1766	29.75	30.25	30.25	--	--	--
	PZ-001D	Segmented PVC Port		< 0.6	1768.5	1766	38.25	38.75	38.75	--	--	--
	PZ-001E	Segmented PVC Port		< 0.6	1768.5	1766	51.75	52.25	52.25	Portable	--	54.50
	PZ-001F	Segmented PVC Port		< 0.6	1768.5	1766	57.75	58.25	58.25	Portable	--	60.50
	PZ-007	Multilevel Piezometer	NASA	--	1771.84	1769.34	--	--	46	--	--	--
	PZ-007A	Segmented PVC Port		< 0.6	1771.84	1769.34	5.75	6.25	6.25	--	--	--
	PZ-007B	Segmented PVC Port		< 0.6	1771.84	1769.34	10.75	11.25	11.25	--	--	--
	PZ-007C	Segmented PVC Port		< 0.6	1771.84	1769.34	15.75	16.25	16.25	--	--	--
	PZ-007D	Segmented PVC Port		< 0.6	1771.84	1769.34	24.75	25.25	25.25	--	--	--
	PZ-007E	Segmented PVC Port		< 0.6	1771.84	1769.34	30.75	31.25	31.25	--	--	--
	PZ-007F	Segmented PVC Port		< 0.6	1771.84	1769.34	35.75	36.25	36.25	--	--	--
	PZ-007G	Segmented PVC Port		< 0.6	1771.84	1769.34	45	45	45	Portable	--	47.50
	PZ-139	Piezometer	NASA	2	1831.91	1829.62	52	62	65	Portable	--	59.29
	PZ-140	Piezometer	NASA	2	1832.82	1833.15	52	62	65	--	--	--
	PZ-141	Piezometer	NASA	2	1856.58	1857.14	21	31	33	Portable	--	25.44
	PZ-147	Piezometer	NASA	2	1791.24	1791.44	27	37	39	--	--	--
	RD-09	Extraction Well	NASA	8.625	1768.49	1767.69	37	200	200	Bladder (QED Well Wizard ST1102M)	45.7 75.7 105.7 135.7 165.7 195.7	--
	RD-26	Monitoring Well	NASA	6.5	1880.78	1880.83	30	160	160	--	--	--
	RD-56A	Multilevel Monitoring Well	NASA	6.5	1758.15	1757.79	20.5	397.5	397.5	FLUTe ports	--	--
	RD-56A-1	FLUTe Port		--	--	--	325	340	--	--	--	--
	RD-56A-2	FLUTe Port		--	--	--	358	373	--	--	--	--
	RD-56A-3	FLUTe Port		--	--	--	382.5	397.5	--	--	--	--
	RD-56B	Monitoring Well	NASA	6.5	1761.31	1761.1	443	463	463	Bladder (QED Well Wizard ST1102M)	453	--
	RD-68A	Monitoring Well	NASA	6.25	1307.97	1306.06	19	90	90	--	--	--
	RD-68B	Monitoring Well	NASA	11.875	1310.96	1309.01	240	270	272	--	--	--
	RD-70	Monitoring Well	NASA	6.5	1732.44	1731.01	19	278	278	--	--	--
	SP-29A	Seep Well	NASA	0.5	1264.68	1263.73	2.8	3.8	3.8	--	--	--
	SP-29B	Seep Well	NASA	0.5	1267.44	1266.61	12.2	15.2	15.2	Artesian	--	--
	SP-29C	Seep Well	NASA	0.5	1265.34	1264.73	1.96	21.96	21.96	Artesian	--	--
	SP-30A	Seep Well	NASA	0.742	1107.35	1106.88	11.39	15.39	15.39	--	--	--
	SP-30B	Seep Well	NASA	0.742	1107.39	1107.05	19.99	24.99	24.99	Peristaltic	--	22.49
	SP-30C	Seep Well	NASA	0.742	1107.27	1106.97	33.58	39.58	39.58	--	--	--
	SP-30D	Seep Well	NASA	0.742	1107.47	1107.06	52.1	54.1	54.1	Peristaltic	--	53.10
	SP-33A	Seep Well	NASA	0.5	1580.84	1580.22	6.11	8.02	8.02	Artesian	--	--
	SP-33B	Seep Well	NASA	0.5	1580.72	1580.38	11.63	14.26	14.26	--	--	--
	SP-33C	Seep Well	NASA	0.5	1578.54	1578.35	21.46	23.4	23.4	Artesian	--	--

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Coca/Delta	C-6	Monitoring Well	NASA	5 to 12	1711.86	1711.09	734.7	884.7	885	Bladder (QED Well Wizard T1200M)	850	--
	FDP-882	Spring	Boeing/NASA	--	--	--	--	--	--	--	--	--
	HAR-07	Extraction Well	NASA	8	1728.72	1728.16	30	100	100	Grundfos Model 5S10-22	95	--
	HAR-08	Monitoring Well	NASA	8	1731.22	1729.64	30	130	130	--	--	--
	HAR-17	Extraction Well	Boeing	8	1711.59	1710.49	30	100	100	Portable	--	66.10
	HAR-27	Monitoring Well	NASA	4	1719.28	1717.59	21	40	40	--	--	--
	HAR-29	Monitoring Well	NASA	4	1724.04	1720.13	20	40.2	40.2	--	--	--
	ND-113	Multilevel Monitoring Well	NASA	6 1/2	1844.75	1845.49	25	651.6	651.6	FLUTe ports	--	--
	ND-113-1	FLUTe Port		--	--	--	197	212	--	--	--	--
	ND-113-2	FLUTe Port		--	--	--	328	343	--	--	--	--
	ND-113-3	FLUTe Port		--	--	--	525	540	--	--	--	--
	ND-114	Multilevel Monitoring Well	NASA	6	1823.03	1823.64	25	675	675	FLUTe ports	--	--
	ND-114-1	FLUTe Port		--	--	--	152	167	--	--	--	--
	ND-114-2	FLUTe Port		--	--	--	225	240	--	--	--	--
	ND-114-3	FLUTe Port		--	--	--	406	421	--	--	--	--
	ND-114-4	FLUTe Port		--	--	--	660	675	--	--	--	--
	ND-115	Multilevel Monitoring Well	NASA	3.33	1698.5	1699.35	29	519.4	519.4	FLUTe ports	--	--
	ND-115-1	FLUTe Port		--	--	--	79	94	--	--	--	--
	ND-115-2	FLUTe Port		--	--	--	270	285	--	--	--	--
	ND-115-3	FLUTe Port		--	--	--	415	430	--	--	--	--
	ND-115-4	FLUTe Port		--	--	--	486	501	--	--	--	--
	ND-116	Multilevel Monitoring Well	NASA	5 to 6	1796.44	1796.96	20	538	538	FLUTe ports	--	--
	ND-116-1	FLUTe Port		--	--	--	130	145	--	--	--	--
	ND-116-2	FLUTe Port		--	--	--	155	170	--	--	--	--
	ND-116-3	FLUTe Port		--	--	--	262	277	--	--	--	--
	ND-116-4	FLUTe Port		--	--	--	304	319	--	--	--	--
	ND-116-5	FLUTe Port		--	--	--	420	435	--	--	--	--
	ND-116-6	FLUTe Port		--	--	--	500	515	--	--	--	--
	ND-117	Monitoring Well	NASA	8	1672.62	1672.06	13	111	111	--	--	--
	PZ-004A	Piezometer	NASA	2	1716	1713.2	5	15	16	--	--	--
	PZ-047	Piezometer	NASA	2	1835.51	1832.4	26	36	40.4	--	--	--
	RD-05A	Monitoring Well	NASA	6.25	1704.78	1704.5	29.5	158	158	--	--	--
	RD-05B	Monitoring Well	NASA	9.875	1706.19	1704.74	257.6	310	310	--	--	--
	RD-05C	Monitoring Well	NASA	6.25	1705.27	1704.28	421	480	480	--	--	--
	RD-06	Monitoring Well	Boeing	8.625	1617.22	1614.82	70	260	260	ES-VFD (Grundfos RediFlo4-5E8)	167	--
	RD-40	Monitoring Well	NASA	6.25	1972.05	1971.18	19.5	300	300	--	--	--
	RD-41A	Monitoring Well	NASA	6.25	1773.71	1772.94	19.5	120	120	--	--	--
	RD-41B	Monitoring Well	NASA	5.875	1774.73	1773.81	340	390	390	ES-VFD (Grundfos Model 5S10-22)	365	--
	RD-41C	Monitoring Well	NASA	6.25	1773.73	1772.7	492	558	558	--	--	--
	RD-79	Monitoring Well	NASA	3 7/8 to 4 7/8	1874.01	1873.81	10	55	55	Portable	--	32.7
	RS-10	Monitoring Well	NASA	4	1762.08	1762.08	7.3	17	17	--	--	--
	SP-881A	Seep Well	Boeing/NASA	0.5	1618.67	1618.2	4.59	6.1	5.65	--	--	--
	SP-881B	Seep Well	Boeing/NASA	0.5	1618.66	1618.29	6.69	7.1	7.7	Peristaltic	--	7.27
	SP-881C	Seep Well	Boeing/NASA	0.5	1618.77	1618.31	14.19	15	15.15	Peristaltic	--	15.06
	SP-881D	Seep Well	Boeing/NASA	0.5	1618.18	1617.76	19.14	20.2	20.2	--	--	--
	SP-881G	Seep Well	Boeing/NASA	0.5	1617.67	1617.24	47.57	52.72	52.72	Peristaltic	--	50.58

TABLE 3

Summary of Construction Data for NASA Sitewide Groundwater Monitoring Program Wells

NASA-specific Sitewide Groundwater Quality Sampling and Analysis Plan, SSFL, Ventura, California

AIG	Well ID	Type	Owner	Well Diameter (inches)	Top of Casing Elevation (ft msl)	Ground Surface Elevation (ft msl)	Screen or Open Interval Top (ft bgs)	Screen or Open Interval Bottom (ft bgs)	Total Well Depth (ft bgs)	Pump Type	Pump Inlet Depth (if dedicated) (ft BTOC)	Minimum Portable Pump Inlet Target Depth[a] (ft BTOC)
Coca/Delta cont.	SP-882A	Seep Well	Boeing/NASA	0.9	1611.94	1611.53	4	5	5	Peristaltic	--	5.26
	SP-882B	Seep Well	Boeing/NASA	0.9	1612.28	1611.92	9.2	10.2	10.2	Peristaltic	--	10.06
	SP-882C	Seep Well	Boeing/NASA	0.622	1611.95	1611.57	13.9	14.1	14.8	Peristaltic	--	14.38
	SP-882D	Seep Well	Boeing/NASA	0.622	1612.01	1611.61	19.1	20.1	20.1	--	--	--
	SP-882G	Seep Well	Boeing/NASA	0.5	1612.21	1611.8	45.92	51	51	Peristaltic	--	48.91
	SP-890A	Seep Well	Boeing/NASA	0.9	1627.51	1627.1	4.2	5.2	5.2	--	--	--
	SP-890B	Seep Well	Boeing/NASA	0.9	1627.91	1627.5	10.3	11.2	11.2	--	--	--
	SP-890C	Seep Well	Boeing/NASA	0.622	1627.31	1626.87	13.9	16.1	16.8	Peristaltic	--	15.44
	SP-890D	Seep Well	Boeing/NASA	0.622	1627.39	1626.98	17.8	19.11	19.92	--	--	--
	SP-890G	Seep Well	Boeing/NASA	0.5	1628.12	1627.73	46.13	54.2	51.02	Peristaltic	--	50.55
	WS-09A	Extraction Well	NASA	8 1/4	1647.61	1645.86	20	539	541	Grundfos Model 10S30-34	60	--
Former LOX Plant	ND-111	Multilevel Monitoring Well	NASA	6	1773.75	1770.02	20.5	300	300	FLUTe ports	--	--
	ND-111-1	FLUTe Port		--	--	--	167	182	--	--	--	--
	ND-111-2	FLUTe Port		--	--	--	235	250	--	--	--	--
	ND-111-3	FLUTe Port		--	--	--	270	285	--	--	--	--
	ND-112	Multilevel Monitoring Well	NASA	3.78	1760.43	1756.21	29	300	300	FLUTe ports	--	--
	ND-112-1	FLUTe Port		--	--	--	59	74	--	--	--	--
	ND-112-2	FLUTe Port		--	--	--	130	145	--	--	--	--
	ND-112-3	FLUTe Port		--	--	--	240	255	--	--	--	--
	ND-112-4	FLUTe Port		--	--	--	290	300	--	--	--	--
	RD-52A	Monitoring Well	Boeing	6.5	1755.76	1755.5	19.5	137	137	Bladder (QED Well Wizard T1250)	130.67	--
	RD-69	Monitoring Well	NASA	6.25	1831.03	1830.3	19	103	103	--	--	--
	RD-80	Monitoring Well	NASA	4.8	1739.88	1738.29	19	224	224	--	--	--
	RD-81	Multilevel Monitoring Well	NASA	6.6	1705.88	1706.16	20	205	205	FLUTe ports	--	--
	RD-81-1	FLUTe Port		--	--	--	114	129	--	--	--	--
	RD-81-2	FLUTe Port		--	--	--	155	170	--	--	--	--
	RD-81-3	FLUTe Port		--	--	--	178	193	--	--	--	--
	RD-81-4	FLUTe Port		--	--	--	200	205	--	--	--	--
	WS-04A	Monitoring Well	NASA	--	1750.99	1750.19	96	502	502	--	--	--
	WS-12	Monitoring Well	NASA	12	1706.26	1706.23	375	1768	1768	Portable ES-VFD	--	379[b]
	WS-13	Monitoring Well	NASA	11.5	1658.9	1658.69	22	940	940	Portable ES-VFD	--	345[b]

[a] Minimum pump depth has been calculated to target the middle of the well screen or open corehole, assuming that the well screen or the open corehole is inundated. Depth takes into account top of casing with respect to ground surface (if BOTH information are available and not equal).

[b] Listed depth is the targeted pump inlet depth (not the minimum target depth).

-- = Information is either not applicable or not available

AIG = Area of Impacted Groundwater

B204 = Building 204

bgs = below ground surface

Boeing = The Boeing Company

BTOC = below top of casing

ELV = Expendable Launch Vehicle

ES-VFD = electric submersible pump with variable-frequency drive

FLUTe = Flexible Liner Underground Technologies

ft = foot (feet)

ID = identification number

LOX = liquid oxygen

msl = mean sea level

NASA = National Aeronautics and Space Administration

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Figures

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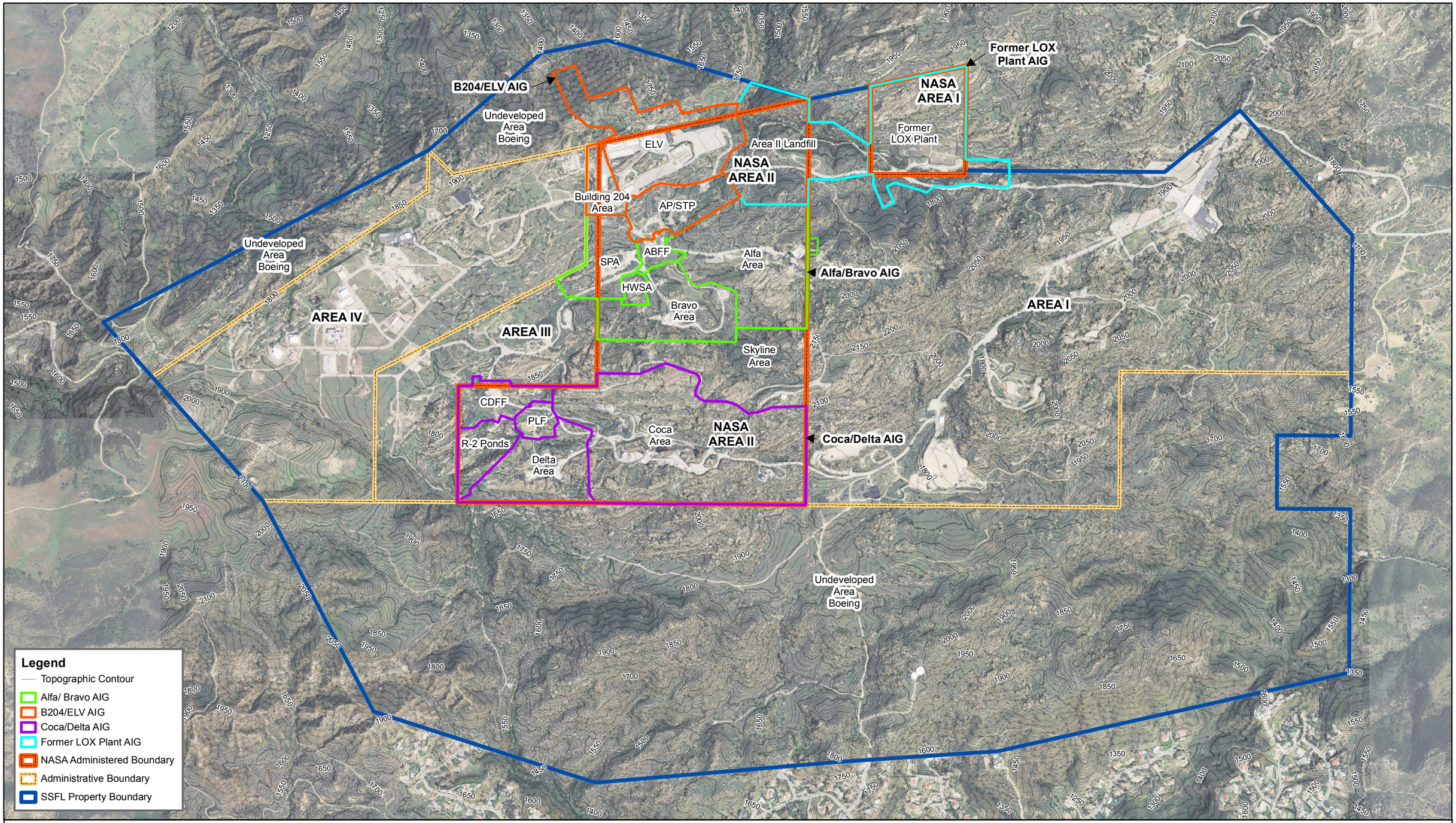

19-Dec-2017
Drawn By:
A. Cooley

Figure 1-1
NASA AIG Locations
NASA-specific Sitewide Groundwater Quality SAP
Santa Susana Field Laboratory
Ventura County, California

Map Document: O:\NASA\SSFL\maps\Groundwater\SAP\AIG_Overview_SAP.mxd

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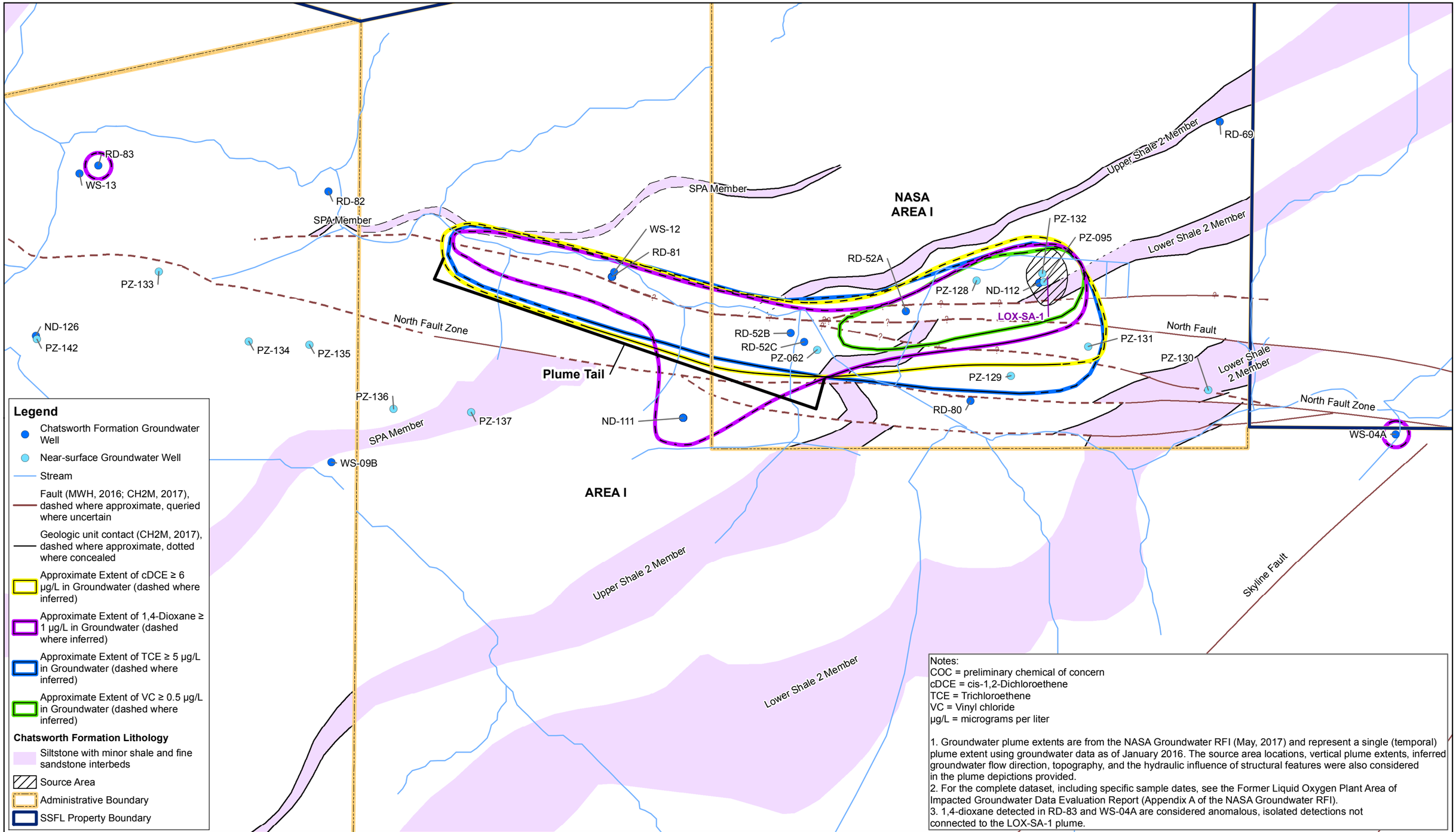

Notes:
COC = preliminary chemical of concern
cDCE = cis-1,2-Dichloroethene
TCE = Trichloroethene
VC = Vinyl chloride
µg/L = micrograms per liter

1. Groundwater plume extents are from the NASA Groundwater RFI (May, 2017) and represent a single (temporal) plume extent using groundwater data as of January 2016. The source area locations, vertical plume extents, inferred groundwater flow direction, topography, and the hydraulic influence of structural features were also considered in the plume depictions provided.
2. For the complete dataset, including specific sample dates, see the Former Liquid Oxygen Plant Area of Impacted Groundwater Data Evaluation Report (Appendix A of the NASA Groundwater RFI).
3. 1,4-dioxane detected in RD-83 and WS-04A are considered anomalous, isolated detections not connected to the LOX-SA-1 plume.

08-Feb-2018
Drawn By:
A. Cooley

Figure 1-2
2016 Extent of COCs in Groundwater, Former LOX Plant AIG
NASA-specific Sitewide Groundwater Quality SAP
Santa Susana Field Laboratory
Ventura County, California

Map Document: O:\NASA\SSFL\maps\Groundwater\SAP\LOX_GW_COCs_SAP.mxd

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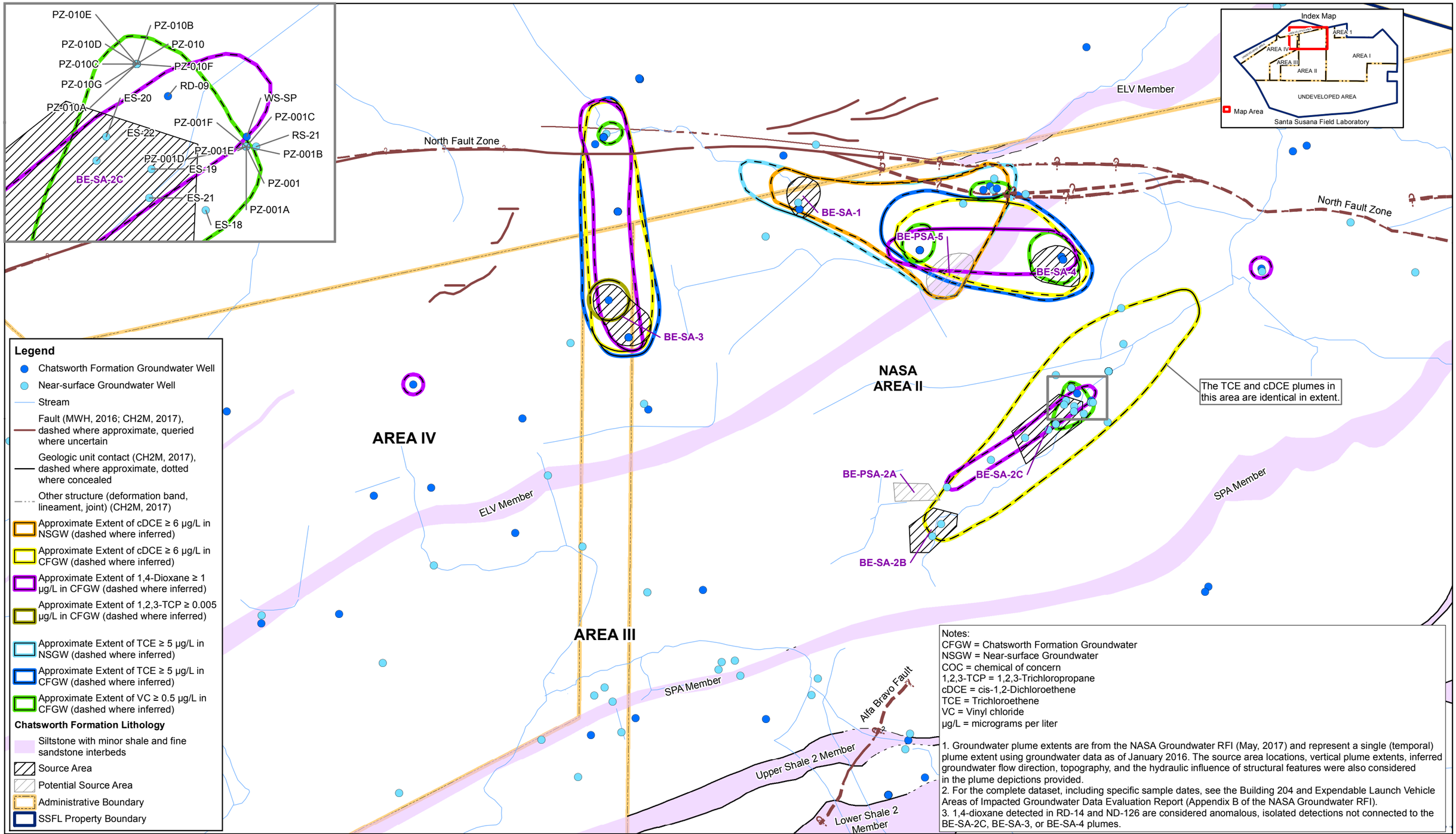
PZ-010E
PZ-010B
PZ-010D
PZ-010
PZ-010C
PZ-010F
PZ-010G
RD-09
ES-20
PZ-010A
WS-SP
PZ-001C
PZ-001F
ES-22
RS-21
PZ-001E
PZ-001B
PZ-001D
ES-19
BE-SA-2C
PZ-001
ES-21
PZ-001A
ES-18
Index Map
AREA 1
AREA IV
AREA I
AREA III
AREA II
UNDEVELOPED AREA
Map Area
Santa Susana Field Laboratory
North Fault Zone
ELV Member
BE-SA-1
BE-PSA-5
BE-SA-4
BE-SA-3
NASA
AREA II
The TCE and cDCE plumes in this area are identical in extent.
AREA IV
BE-PSA-2A
BE-SA-2C
BE-SA-2B
SPA Member
AREA III
Alfa Bravo Fault
Upper Shale 2 Member
Lower Shale 2 Member
Legend
Chatsworth Formation Groundwater Well
Near-surface Groundwater Well
Stream
Fault (MWH, 2016; CH2M, 2017), dashed where approximate, queried where uncertain
Geologic unit contact (CH2M, 2017), dashed where approximate, dotted where concealed
Other structure (deformation band, lineament, joint) (CH2M, 2017)
Approximate Extent of cDCE ≥ 6 µg/L in NSGW (dashed where inferred)
Approximate Extent of cDCE ≥ 6 µg/L in CFGW (dashed where inferred)
Approximate Extent of 1,4-Dioxane ≥ 1 µg/L in CFGW (dashed where inferred)
Approximate Extent of 1,2,3-TCP ≥ 0.005 µg/L in CFGW (dashed where inferred)
Approximate Extent of TCE ≥ 5 µg/L in NSGW (dashed where inferred)
Approximate Extent of TCE ≥ 5 µg/L in CFGW (dashed where inferred)
Approximate Extent of VC ≥ 0.5 µg/L in CFGW (dashed where inferred)
Chatsworth Formation Lithology
Siltstone with minor shale and fine sandstone interbeds
Source Area
Potential Source Area
Administrative Boundary
SSFL Property Boundary
Notes:
CFGW = Chatsworth Formation Groundwater
NSGW = Near-surface Groundwater
COC = chemical of concern
1,2,3-TCP = 1,2,3-Trichloropropane
cDCE = cis-1,2-Dichloroethene
TCE = Trichloroethene
VC = Vinyl chloride
µg/L = micrograms per liter
1. Groundwater plume extents are from the NASA Groundwater RFI (May, 2017) and represent a single (temporal) plume extent using groundwater data as of January 2016. The source area locations, vertical plume extents, inferred groundwater flow direction, topography, and the hydraulic influence of structural features were also considered in the plume depictions provided.
2. For the complete dataset, including specific sample dates, see the Building 204 and Expendable Launch Vehicle Areas of Impacted Groundwater Data Evaluation Report (Appendix B of the NASA Groundwater RFI).
3. 1,4-dioxane detected in RD-14 and ND-126 are considered anomalous, isolated detections not connected to the BE-SA-2C, BE-SA-3, or BE-SA-4 plumes.
N
W
E
S
0 250 500 1,000 Feet
0 75 150 300 Meters
08-Feb-2018
Drawn By:
A. Cooley

Figure 1-3
2016 Extent of COCs in Groundwater, B204/ELV AIG
NASA-specific Sitewide Groundwater Quality SAP
Santa Susana Field Laboratory
Ventura County, California

Map Document: O:\NASA\SSFL\maps\Groundwater\SAP\BE_GW_COCs_SAP.mxd

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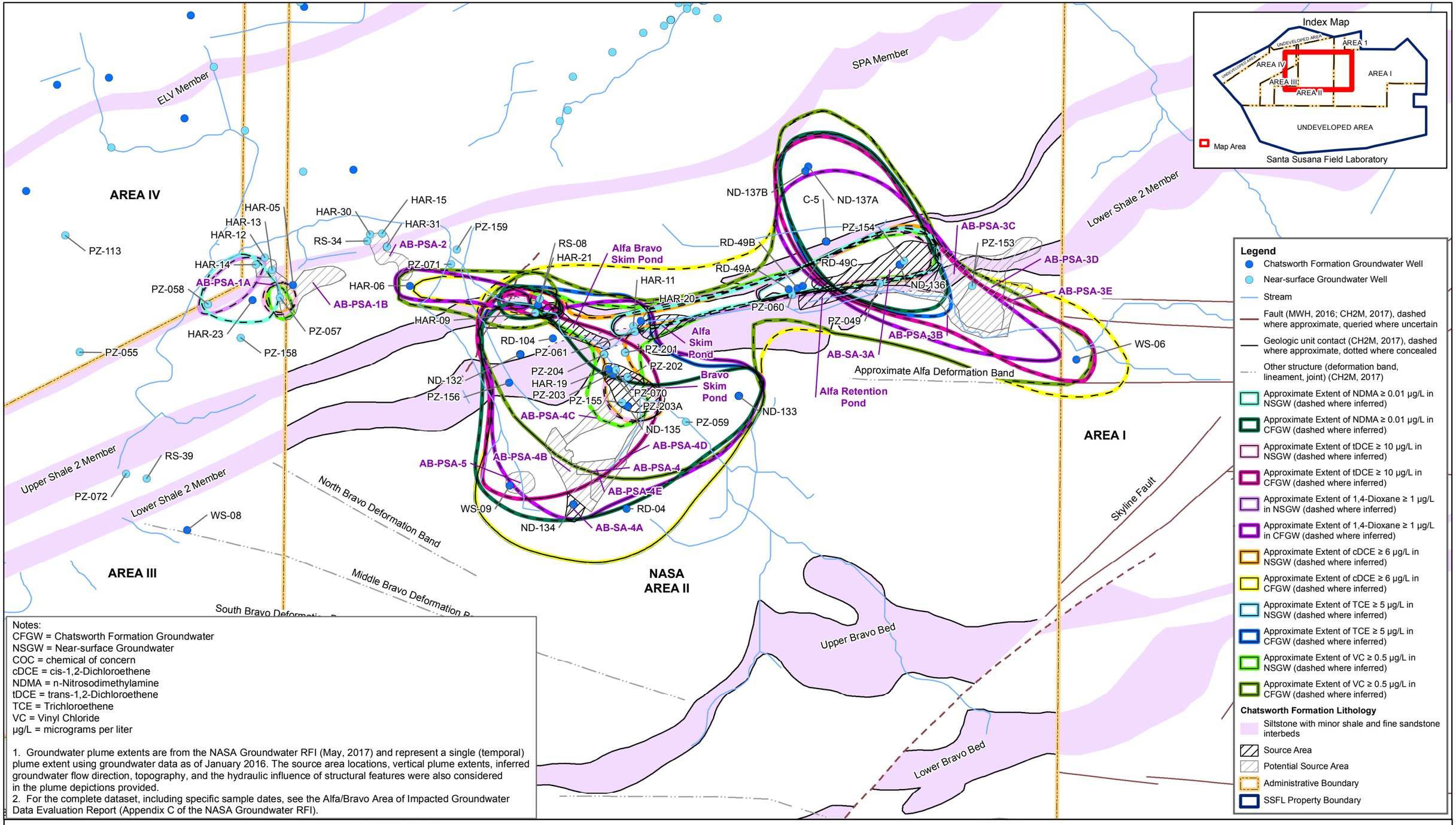

Legend

- Chatsworth Formation Groundwater Well
- Near-surface Groundwater Well
- Stream
- Fault (MWH, 2016; CH2M, 2017), dashed where approximate, queried where uncertain
- Geologic unit contact (CH2M, 2017), dashed where approximate, dotted where concealed
- Other structure (deformation band, lineament, joint) (CH2M, 2017)
- Approximate Extent of NDMA ≥ 0.01 µg/L in NSGW (dashed where inferred)
- Approximate Extent of NDMA ≥ 0.01 µg/L in CFGW (dashed where inferred)
- Approximate Extent of tDCE ≥ 10 µg/L in NSGW (dashed where inferred)
- Approximate Extent of tDCE ≥ 10 µg/L in CFGW (dashed where inferred)
- Approximate Extent of 1,4-Dioxane ≥ 1 µg/L in NSGW (dashed where inferred)
- Approximate Extent of 1,4-Dioxane ≥ 1 µg/L in CFGW (dashed where inferred)
- Approximate Extent of cDCE ≥ 6 µg/L in NSGW (dashed where inferred)
- Approximate Extent of cDCE ≥ 6 µg/L in CFGW (dashed where inferred)
- Approximate Extent of TCE ≥ 5 µg/L in NSGW (dashed where inferred)
- Approximate Extent of TCE ≥ 5 µg/L in CFGW (dashed where inferred)
- Approximate Extent of VC ≥ 0.5 µg/L in NSGW (dashed where inferred)
- Approximate Extent of VC ≥ 0.5 µg/L in CFGW (dashed where inferred)

Chatsworth Formation Lithology

- Siltstone with minor shale and fine sandstone interbeds
- Source Area
- Potential Source Area
- Administrative Boundary
- SSFL Property Boundary

Notes:
CFGW = Chatsworth Formation Groundwater
NSGW = Near-surface Groundwater
COC = chemical of concern
cDCE = cis-1,2-Dichloroethene
NDMA = n-Nitrosodimethylamine
tDCE = trans-1,2-Dichloroethene
TCE = Trichloroethene
VC = Vinyl Chloride
µg/L = micrograms per liter

1. Groundwater plume extents are from the NASA Groundwater RFI (May, 2017) and represent a single (temporal) plume extent using groundwater data as of January 2016. The source area locations, vertical plume extents, inferred groundwater flow direction, topography, and the hydraulic influence of structural features were also considered in the plume depictions provided.
2. For the complete dataset, including specific sample dates, see the Alfa/Bravo Area of Impacted Groundwater Data Evaluation Report (Appendix C of the NASA Groundwater RFI).

0 125 250 500 Feet
0 37.5 75 150 Meters

08-Feb-2018
Drawn By:
A. Cooley

Figure 1-4
2016 Extent of COCs in Groundwater, Alfa/Bravo AIG
NASA-specific Sitewide Groundwater Quality SAP
Santa Susana Field Laboratory
Ventura County, California

Map Document: O:\NASA\SSFL\maps\Groundwater\SAP\AB_GW_COCs_SAP.mxd

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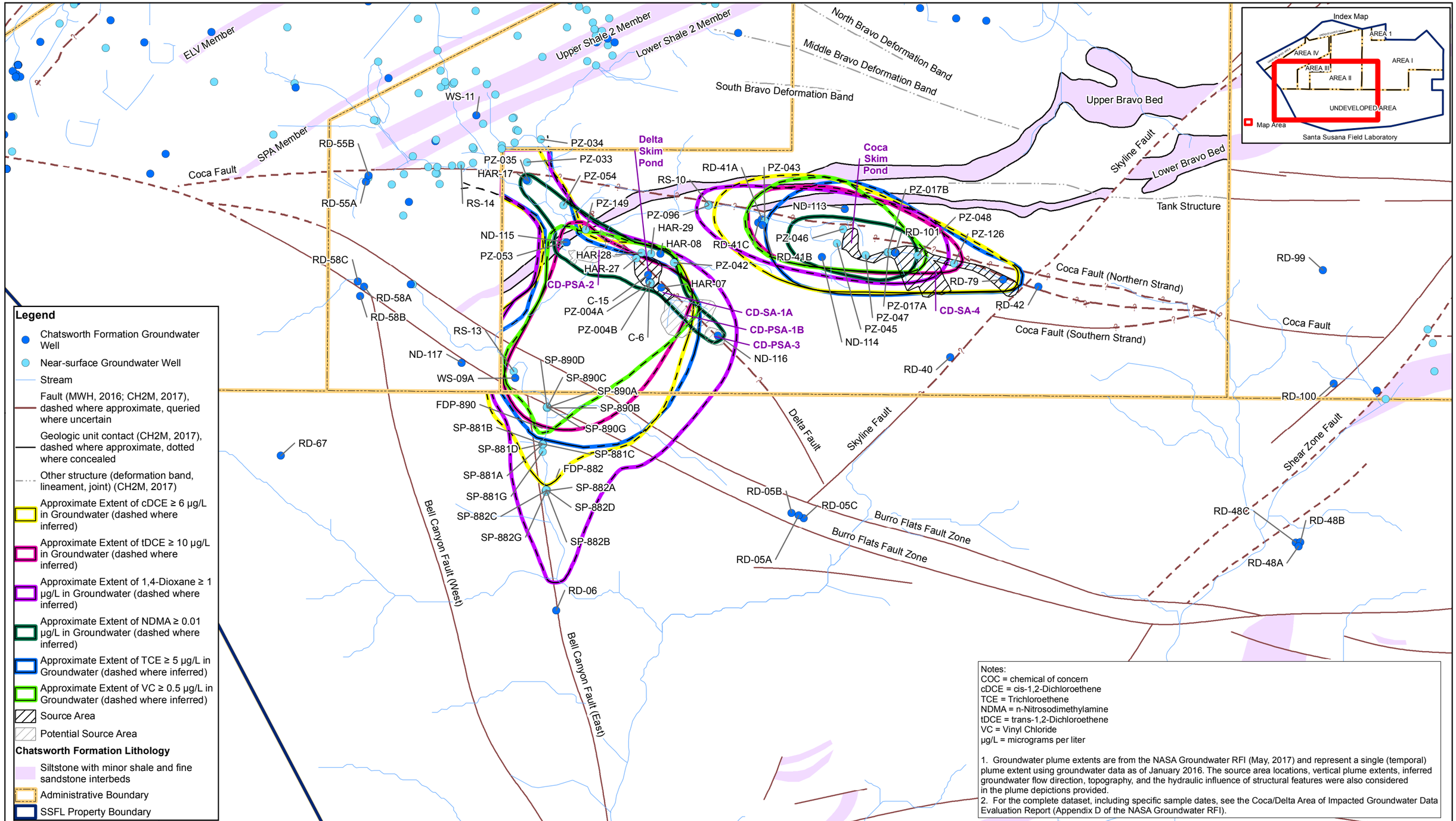

Figure 1-5
2016 Extent of COCs in Groundwater, Coca/Delta AIG
NASA-specific Sitewide Groundwater Quality SAP
Santa Susana Field Laboratory
Ventura County, California

Map Document: O:\NASA\SSFL\maps\Groundwater\SAP\CD_GW_COCs_SAP.mxd

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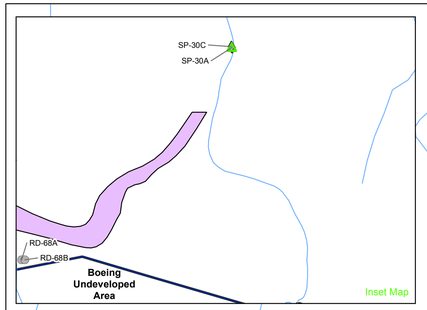

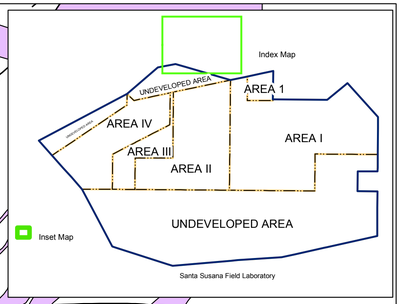

RI Sites

Group 1A

A1LF	Area 1 Landfill
APTF	Advanced Propulsion Test Facility
B-1	B-1 Area
B359	Building 359 Sump Area
CYN	Canyon Area
HVN	Happy Valley North
HVS	Happy Valley South
IEL	Instrument and Equipment Laboratories
LETF	Laser Engineering Test Facility

Group 1B

Area I Burn Pit	Area I Burn Pit
Bowl Area	Bowl Area
CTL-V	Component Test Laboratory V
CTL-III	Component Test Laboratory III
Perimeter Pond	Perimeter Pond
R-1 Pond	R-1 Pond

Group 2

LOX	Liquid Oxygen Plant
ELV	Expendable Launch Vehicle
Ash Pile	Former Incinerator Ash Pile
B515 STP	Building 515 Sewage Treatment Plant
Area II Landfill	Area II Landfill

Group 3

B204	Building 204 Area
Alfa	Alfa Area
Bravo	Bravo Area
SPA	Storable Propellant Area
ABFF	Alfa/Bravo Fuel Farm
HWSA	Hazardous Waste Storage Area
WCT	Waste Coolant Tank

Group 4

Coca	Coca Area
Delta	Delta Area
PLF	Propellent Load Facility

Group 5

B100	Building 100 Trench
Metals Clarifier	Building 65, Metals Laboratory Clarifier
Boeing LF	Building 008 Warehouse
Compound A	Compound A Facility
DOE LF 1	Department of Energy Leach Field 1
DOE LF 2	Department of Energy Leach Field 2
DOE LF 3	Department of Energy Leach Field 3
ECL	Engineering Chemistry Laboratory
EEL	Environmental Effects Laboratory
HMSA	Hazardous Materials Storage Area
PDU	Process Development Unit
Pond Dredge	Pond Dredge Area
RIHL	Rockwell International Hot Laboratory
SE Drum	Southeast Drum Storage Yard
SNAP	Systems for Nuclear Auxiliary Power Facility
STL-IV	Systems Test Laboratory IV
STP-3	Sewage Treatment Plant Pond

Group 6

B064 LF	Building 064 Leach Field
NCY	New Conservation Yard
OCY	Old Conservation Yard
SRE	Sodium Reactor Experiment

Group 7

B4133	Building 4133 Hazardous Waste Management Facility
RMHF	Radioactive Material Disposal Facility
B4029	Building 029 Reactive Metal Storage Yard

Group 8

B009 LF	B009 Leach Field
B056 LDFL	Building 56 Landfill
ESADA	ESADA Chemical Storage Area
FSDF	Former Sodium Disposal Facility

Group 9

R-2 Ponds	R-2A and R-2B Ponds
CDFF	Coca/Delta Fuel Farm

Notes:
NSGW = Near-surface groundwater
CFGW = Chatsworth Formation groundwater
NA = natural attenuation
COC = constituent of concern

1. COC-only groundwater quality sample locations will be sampled annually for COCs, as indicated in Table 2.
2. NA groundwater quality sample locations will be sampled biannually for NA parameters, in addition to annual COC sampling.
3. Water levels will be measured quarterly at groundwater/surface water level measurement locations, and at groundwater quality sample locations as indicated in Table 2.
4. Water level monitoring at FDP-882 will consist of noting whether this seep location is wet, flowing, or contains standing water.

Legend

Groundwater Quality Sample Locations - COCs only
- CFGW Well
- Multi-level Monitoring Well (CFGW)
- Seep/Spring

Groundwater Quality Sample Locations - NA
- CFGW Well
- NSGW Well
- Multi-level Piezometer (NSGW)
- Multi-level Monitoring Well (CFGW)
- Seep/Spring

Groundwater/Surface Water Level Measurement Locations
- CFGW Well
- NSGW Well
- Fault - location accurate, identity and existence certain
- Fault - location inferred, identity and existence certain
- Fault - location inferred, identity and existence uncertain
- Stream
- Fine-grained Unit, dashed where inferred
- RCRA-regulated Unit
- Pond or Impoundment (current or historic)
- General Site Area including SWMU or AOC
- RI Group
- Administrative Boundary
- SSFL Property Boundary

0 500 1,000 2,000 Feet

0 150 300 600 Meters

19-Dec-2017
Drawn By:
A. Cooley

Figure 2-1
NASA Monitoring Well Network
NASA-specific Sitewide Groundwater Quality SAP
Santa Susana Field Laboratory
Ventura County, CA

Map Document: O:\NASA\SSFL\maps\Groundwater\SAP\2017_WQSAP_Wells_SAP.mxd

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Appendix A
Field Sampling Plan

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Appendix A

NASA Sitewide Groundwater Field Sampling Plan Santa Susana Field Laboratory Ventura County, California

Prepared for

National Aeronautics and Space Administration

February 2018

Contents

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2.4 Sample Management 2-3
2.5 Decontamination and Demobilization 2-3
2.6 Waste Management Planning 2-4

3 Project Organization **3-1**

4 References **4-1**

Attachment

1 Standard Operating Procedures

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Acronyms and Abbreviations

AIG	area of impacted groundwater
COC	chemical of concern
EM	Environmental Manager
FLUTe	Flexible Liner Underground Technologies
FSP	Field Sampling Plan
FTL	Field Team Leader
GWQSAP	Groundwater Quality Sampling and Analysis Plan
IDW	investigation-derived waste
mL/min	milliliter(s) per minute
NASA	National Aeronautics and Space Administration
PID	photoionization detector
PM	Project Manager
SOP	Standard Operating Procedures
SPA	Storable Propellant Area
SSFL	Santa Susana Field Laboratory
UFP-QAPP	Uniform Federal Policies for Quality Assurance Project Plan
VOA	volatile organic analytics
VOC	volatile organic compound

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SECTION 1

Purpose and Scope

The National Aeronautics and Space Administration (NASA)-specific Sitewide Groundwater Quality Sampling and Analysis Plan (GWQSAP) provides information regarding the NASA-specific sitewide groundwater monitoring program at the Santa Susana Field Laboratory (SSFL). The purpose of this NASA Sitewide Groundwater Field Sampling Plan (FSP) is to describe the methodologies to be implemented in the field during sitewide groundwater monitoring events. This FSP is Appendix A of the NASA-specific Sitewide GWQSAP.

The overall purpose of the groundwater monitoring plan is to:

- Collect analytical data with which to evaluate long-term trends in chemicals of concern (COCs) or general groundwater quality at NASA areas of impacted groundwater (AIGs)
- Provide data to evaluate the spatial distribution of COCs in groundwater at NASA AIGs
- Provide data to support evaluation of whether COCs in groundwater pose a risk to human or environmental health
- Provide data to evaluate the occurrence of natural degradation processes associated with chlorinated volatile organic compounds (VOCs) and fuel-related compounds

The methodologies described in this FSP were prepared to support the NASA-specific Sitewide GWQSAP. The monitoring well network, analytical suites, analytical methods, and sampling frequencies are described in the NASA-specific Sitewide GWQSAP.

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SECTION 2

Field Sampling Procedures

This section describes the field procedures for the NASA Sitewide Groundwater Monitoring Program. The standard operating procedures (SOPs) specified in the following sections are provided in Attachment 1.

2.1 Water Level Gauging

Water level gauging will be conducted as follows:

- Depth to groundwater will be measured at monitoring wells before any groundwater sampling activities, in accordance with the Manual Water Level Measurements SOP.
- Before field use, depth-to-water probes must be measured to verify accuracy. The 1-foot marker on the probe tape should correspond to a 1-foot distance between the probe sensor and the marker; if it does not, then adjustments will need to be made to water level readings.
- Water level measurements should be recorded on the appropriate field form.
- Downhole water level meters must be decontaminated before use at each well to avoid cross-contamination between wells. Decontamination activities will follow the Equipment Decontamination SOP.

The following procedures will be used to measure water levels in wells containing the Flexible Liner Underground Technologies (FLUTe) sampling system (if included in the monitoring network):

- Obtain the water level for each port using the transducers. For all ports where the water level is shallower than 160 feet below ground surface, also measure and record the water level in the air line for each port manually using a water level meter, only after the port has been purged and the water level has stabilized.
- Verify that the water level in the liner is at least 10 feet higher than the water level in the uppermost port. Add potable water to the inside of the liner if the water level is less than 10 feet higher than the shallowest water level in the ports (usually, this is the uppermost port).
- Upon the eventual failure of dedicated downhole pressure transducers at FLUTe wells, an air-coupled transducer system will need to be set up and used to obtain approximate water levels.

The physical condition of each well will also be observed during gauging activities and recorded on the appropriate field form. Field staff should evaluate the following:

- The integrity of the well casing, monument, pad, gaskets, and/or plugs, identifying marker (sign or paint), and FLUTe fittings and tubes (if applicable)
- Soil erosion that may be undermining the pad
- Any replacement parts that may be required
- Any brush clearance, removal of biological hazards (spiders, wasps, and similar), or road repair is needed to safely access the well

If the condition of a well is such that gauging and sampling will not be feasible and/or safe, the Field Team Leader (FTL) should be notified so that any necessary repairs or site modifications can be coordinated with the Project Manager (PM) and other relevant personnel.

2.2 Groundwater Purging and Sampling

Groundwater purging and sampling will be implemented as follows:

- Photoionization detector (PID) measurements will be taken within the well casing and in the breathing zone at all groundwater monitoring wells. The PID will be calibrated daily following the Equipment Calibration Procedures SOP.
- A portable pump will be used for purging and sample collection in wells or piezometers that do not contain a dedicated pump or multiport FLUTe system. If no pump information is provided, consult the FTL for the appropriate pump to use.
- Low-flow techniques will be used for purging and sampling at all wells that do not have a multilevel groundwater sampling system (that is, FLUTe, Westbay, and similar) in accordance with the Low-Flow Purge and Groundwater Sampling SOP. Sampling will occur when field parameters are stabilized. Individual parameter stabilization will be determined by three consecutive stable parameters recorded no less than 2 minutes apart, as outlined in the Low-Flow Purge and Groundwater Sampling SOP. The water quality meter will be calibrated daily following the Equipment Calibration Procedures SOP. In addition, field team members will:
  - Confirm with the FTL whether a well (with or without a dedicated pump) should be purged or sampled if the water column is less than 3 feet above the:
    - Pump inlet (for dedicated pumps)
    - Bottom of the screen in cased wells
    - Total depth of the uncased well/corehole
  - If the flow rate of a well exceeds 500 milliliters per minute (mL/min), do NOT use the Horiba U-50 series flow-through cell. Fill the measuring cup provided with the Horiba with a grab sample of the purge groundwater from the discharge line/tubing (or bypass spigot). Record that a flow-through cell was not used and how the water quality parameters were measured.
  - If no drawdown is observed, increase the flow rate until drawdown is observed and does not exceed 0.33 foot or until the maximum flow rate of the pump is reached.
  - If drawdown is observed, do not let it exceed 0.33 foot. If drawdown exceeds 0.33 foot, refer to the Low-Flow Purge and Groundwater Sampling SOP for options.
  - Do not start measuring water quality parameters until a single system volume has been purged. System volume is the volume of the tubing and the pump for bladder pumps and volume of the drop pipe for electric submersible pumps having drop pipe.
  - Ensure that the frequency to record the water quality parameters accounts for the flow rate and the amount of time required to “cycle” the groundwater in the flow-through cell.
  - If parameters do not stabilize even after decreasing flow rate, purge groundwater until three system volumes have been purged or until 1 hour after the start of purging, whichever occurs first. Note that the parameters have not stabilized, record the final set of parameters, then proceed with the collection of groundwater samples. Notify the FTL of samples collected in this manner. The FTL will consult with the PM and project chemist to decide whether the samples should be flagged as screening level data (the data flagging will be the responsibility of the Project Chemist).
  - At time of collection, when filling 40-milliliter volatile organic analytics (VOAs) for VOCs or total petroleum hydrocarbon gasoline-range organics, reduce the flow rate to approximately 100 to

150 mL/min. Once all VOAs are filled, the flow rate can be increased to the flow rate used during purging to collect the remaining samples.

- Check that all bolts, if present, on a well vault lid are secured prior to departure. Document any missing bolts on the sampling form and notify the FTL immediately.

- In some instances, it may be necessary to employ alternate groundwater sampling techniques. In such instances, groundwater purging and/or sample collection will follow the appropriate SOP included in Attachment 1 (such as FLUTe, Westbay, and similar procedures).
- After purging, groundwater samples will be collected for the analytical suite specified in the NASA-specific Sitewide GWQSAP. The dissolved metals sample should be field filtered with a 0.45-micron filter. The laboratory will supply sample containers (pre-preserved where needed).
- Before fieldwork, investigation-derived waste (IDW) handling considerations should be discussed with the onsite waste disposal coordinator. The onsite waste disposal coordinator will consult with the Environmental Manager (EM) to ensure proper management of IDW.
- Nondedicated equipment should be decontaminated between sample locations, following the Equipment Decontamination SOP.

2.3 Field Documentation

Field notes should follow the Documentation and Records SOP and staff should complete the appropriate field form.

2.4 Sample Management

Sample handling and shipping should follow the Packaging and Shipping Procedures SOP and Chain-of-Custody Procedures SOP.

Sample labeling should follow the SSFL Uniform Federal Policies for Quality Assurance Project Plan (UFP-QAPP) (Haley & Aldrich, 2010). Each day, field staff should communicate the collected sample identification numbers and times to the sample manager, who will input sample information into the sample tracking and sample procurement database to generate chain(s) of custody and sample labels. The physical documents will then be provided to field staff for preparation of the shipment to the laboratory, using the following procedures:

- At least 1 to 2 hours should be allowed at the end of each day for chain-of-custody/label generation and sample packaging.
- Obtain sample labels for each sampling event from the FTL. Field staff will only need to fill in the sample date, time, and sampler initial fields to complete each label. Staff will still need to communicate sample time information to the field sample manager for generation of chain(s) of custody.

2.5 Decontamination and Demobilization

The field team may construct a temporary decontamination area at the well sites or use the established decontamination area at the 90-day waste accumulation area (located at the Storable Propellant Area [SPA]). A decontamination location will be established before the commencement of field activities. Decontamination activities will follow the Equipment Decontamination SOP. In addition, the decontamination fluids will be placed in containers issued by the EM. Once the decontamination fluids are placed into containers, the EM will be responsible for disposal. Sediment generated from decontamination activities that accumulates in the decontamination area at the SPA must be containerized by the subcontractors in an appropriate container. If there is enough material that can be placed in a shovel or a dustpan, it should be removed.

Field personnel will take care not to track soil onto roadways or off the work area. Vehicle tires should be inspected before leaving the site and any caked-on material should be removed before driving on roadways. Removal can be accomplished by dry brushing or scraping.

If necessary, motorized equipment that is parked onsite should use drip pans or plastic sheeting beneath the equipment to prevent leaking fluids from contacting underlying soil.

Demobilization activities will include removing personnel, equipment, material, instruments, and services brought to the site and no longer required. Demobilization also will include removing waste and debris generated during the remedy implementation and demobilization activities.

2.6 Waste Management Planning

Several weeks before fieldwork, a planning meeting should be held with the EM and onsite waste coordinator to discuss IDW container handling and disposal requirements for the fieldwork. Discussion items should include, but are not limited to, the following:

- Updated IDW volume estimates
- IDW container needs and locations
- Whether the work location is associated with F-listed waste and therefore requires special handling of IDW and PPE (The EM should be contacted before work to verify.)

General waste management information is included in the *Sitewide Waste Management Plan* (NASA, 2014). The EM and onsite waste manager are the team's primary resource for waste management planning and questions. The EM should confirm with the FTL and/or the onsite waste management manager that work is being performed under the latest waste management plans. The onsite waste coordinator and EM will be responsible for tracking, labeling, characterization, and disposal of IDW.

All spills will be reported immediately as specified in the *Sitewide Waste Management Plan* (NASA, 2014).

SECTION 3

Project Organization

The NASA Sitewide groundwater monitoring team will be organized based on the individual roles and responsibilities. During groundwater monitoring activities, these may include (but are not limited to):

- Project Manager
- Field Team Leader
- Field Sampling Team
- Field Sample Manager
- Project Chemist
- Onsite Waste Coordinator
- Environmental Manager
- Site Safety Coordinator

Individual field staff may perform one or more of the roles listed above. Prior to each field sampling plan, field staff will verify that they have read and understand the NASA-specific Sitewide GWQSAP (including this FSP [Appendix A], the QAPP Addendum [Appendix B], and the 2010 QAPP [Haley & Aldrich]). Two weeks prior to each sampling event, the California Department of Toxic Substances Control will be notified of the upcoming event and the schedule.

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SECTION 4

References

Haley & Aldrich, Inc. (Haley & Aldrich). 2010. *Site-Wide Water Quality Sampling and Analysis Plan, Santa Susana Field Laboratory, Ventura County, California.* Revision 1. December.

National Aeronautics and Space Administration (NASA). 2014. *Sitewide Waste Management Plan, NASA Santa Susana Field Laboratory*. September.

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Attachment 1
Standard Operating Procedures

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STANDARD OPERATING PROCEDURE

Equipment Calibration Procedures

1.0 Purpose and Scope

This Standard Operating Procedure (SOP) provides a general guideline for calibration of field instruments. Field instruments will be calibrated daily before beginning sampling activities. Calibration details for the instruments used for each field activity are described below.

2.0 Equipment and Materials

- Organic Vapor Analyzer/ Monitor
- Water Quality Meter including pH, specific conductivity, oxidation-reduction potential, temperature, and dissolved oxygen probes
- Turbidimeter
- Additional equipment/meters requiring calibration
- Calibration gases and standards
- Personal protective equipment (PPE) as specified in the Health and Safety Plan (HASP)

3.0 Procedures and Guidelines

3.1 Organic Vapor

3.1.1 Organic Vapor Analyzer Calibration

The primary calibration of the organic vapor analyzer (OVA) is performed at the factory to 100 parts per million (ppm) methane gas. Secondary calibration will be performed according to manufacturer's specifications at the beginning of each sampling activity. The meter will be zeroed to background levels and calibration logs will be recorded on a daily basis by field personnel.

3.1.2 Organic Vapor Monitor Calibration

The primary calibration of the organic vapor monitor (OVM) is performed at the factory. Secondary calibration will be performed according to manufacturer's specifications at the beginning of each sampling activity. The meter will be zeroed to background levels and calibration logs will be recorded on a daily basis by field personnel.

3.2 Groundwater Sampling

Several instruments will be used during the collection of groundwater samples. Initial monitoring of the ambient air for volatile organic vapors around the wellhead will be performed using an OVA or OVM. The pH, specific conductance, oxidation-reduction potential (ORP), dissolved oxygen (DO), and turbidity meters will be calibrated, compensating for temperature, in the field at the beginning of each day, following the manufacturer's specifications. The calibration procedures are described below and will be carried out by field personnel.

3.2.1 pH Meter Calibration

The pH meters will be calibrated against two sets of standard pH solutions, either 4.0 standard units (SU) and 7.0 SU or 7.0 SU and 10.0 SU, depending on whether previous pH measurements have been less than or greater than 7.0 SU, respectively. At the end of calibration, the meter readings will be adjusted and the probe will be rinsed thoroughly with distilled water. Calibration records will be documented in the field book or on calibration logs. Spent calibration fluids will be disposed of as specified in the Waste Management Plan (WMP).

3.2.2 Specific Conductivity Meter Calibration

The specific conductivity meters will be standardized by immersing the decontaminated conductivity probe into a standard solution of conductivity buffer. The conductivity of the standard solution will be within the same order of magnitude as the water sample. The value of the standard may vary and may be temperature dependent. At the end of calibration, the meter readings will be adjusted and the probe will be rinsed thoroughly with distilled water. Calibration records will be documented in the field book or on calibration logs. Spent calibration fluids will be disposed of as specified in the WMP.

3.2.3 Oxidation-Reduction Potential Meter Calibration

The ORP meters will be standardized by immersing the decontaminated ORP probe into an ORP standard solution. The value of the standard may vary and may be temperature dependent. At the end of calibration, the meter readings will be adjusted and the probe will be rinsed thoroughly with distilled water. Calibration records will be documented in the field book or on calibration logs. Spent calibration fluids will be disposed of as specified in the WMP.

3.2.4 Dissolved Oxygen Meter Calibration

The DO meters will be standardized by thoroughly rinsing the probe in distilled water, then placing the probe in the calibration cup without screwing the cap in place. A small amount of water may remain in the cap, but the probe should not be submersed. The calibrated DO probe should read a saturation percentage near, or at, 100 percent (usually indicated by 8 to 9 milligrams per liter). At the end of calibration, the meter readings will be adjusted and the probe will be rinsed thoroughly with distilled water. Calibration records will be documented in the field book or on calibration logs. Spent calibration fluids will be disposed of as specified in the WMP.

3.2.5 Turbidimeter Calibration/Check

A turbidimeter included as part of a water quality meter will be standardized by immersing the decontaminated turbidity probe into turbidity standard solution of 0 nephelometric turbidity units (NTU). At the end of calibration, the meter readings will be adjusted and the probe will be rinsed thoroughly with distilled water. If a separate turbidimeter is used, the accuracy of the machine will be checked by using NTU standards of three different orders of magnitude and reading on the machine. Calibration records will be documented in the field book or on calibration logs.

4.0 Key Checks

- The water quality meter probes will be rinsed with distilled water before storage each day.
- The meters will be checked for battery charge and physical damage each day.
- The meters, standard solutions, buffers, and gases will be stored in a cool, dry environment and will be discarded upon expiration.

STANDARD OPERATING PROCEDURE

Manual Water Level Measurements

1.0 Purpose and Scope

This Standard Operating Procedure (SOP) provides a general guideline for measurement of depth to groundwater and total depth of borings and/or groundwater monitoring wells/piezometers.

2.0 Equipment and Materials

- Down-hole water level (WL) indicator or oil/water interface probe using a battery-powered probe assembly attached to a cable marked in 0.01-foot increments
- Decontamination equipment: buckets, spray bottles (one with Alconox or Liquinox detergent solution, one with tap water, and one with distilled or deionized [DI] water), paper towels, and absorbent pads
- Personal protective equipment (PPE) as specified in the Health and Safety Plan (HASP)

3.0 Procedures and Guidelines

- With the WL indicator switched on, wet the tip of the probe in potable water to test whether the meter is working properly. If no audible alarm is observed, the meter is not working properly.
- For non-FLUTe or Westbay wells - open flush to grade well box lid with socket set, or open monument with hands. Use key to unlock padlock on well cap. Remove well cap. If the well is sealed with an airtight cap, allow time for pressure to equilibrate after the cap is removed before measuring WLs. Use caution when removing well cap since the well may be under slight pressure (wear PPE as specified in the HASP). For borings – remove sample equipment from hole, if needed.
- Decontaminate WL meter using buckets or spray bottles containing detergent solution wash, tap water rinse, and distilled/DI water rinse.
- Static groundwater level and total depth are measured relative to an established measurement reference point. The measurement reference point is generally the top of the casing and may be marked with a surveyor's reference mark. The reference mark should be permanent, such as a small notch cut into the top of casing or a permanent ink mark at the top of casing. If a reference mark is not present at the time of WL measurement, use permanent ink and mark the north side of the casing.
- Slowly lower the WL meter tape down the monitoring well, piezometer, or borehole until the probe contacts the top of groundwater (as indicated by a solid audible tone).
- Raise the probe out of the water until the audible alarm stops. Continue raising and lowering the probe until a precise level is determined within 0.01 foot.
- For total depth measurements at non-FLUTe or Westbay wells, slowly lower the WL meter (using the same procedures as above) until the cable goes slack. Gently raise and lower the WL meter probe to tap the bottom of the well.
- Record the measurements in the field log book or field datasheet.
- Remove WL tape from well, and decontaminate meter tip/tape using buckets or spray bottles containing detergent solution wash, tap water rinse, and distilled/DI water rinse.

3.1 Multilevel System Wells

The following are a few reminders when measuring WLs in wells containing the FLUTe sampling system:

- Obtain the WL for each port using the transducers. For all ports that are shallower than 160 ft bgs, also measure and record the WL in the airline for each port manually using a WL meter. Use a narrow gauge WL meter (like the Heron Teflon-lined or Solinst skinny-dipper WL meters) only after the port has been purged and the WL has stabilized.
- Verify that the WL in the liner is at least 10 feet higher than the WL in the uppermost port. Add potable water to the inside the liner if the WL is less than 10 feet higher than the shallowest WL in the ports (usually, this is the uppermost port).

For Westbay multilevel wells, special equipment is required to measure WLs. Westbay-trained personnel should be contacted for appropriate equipment and procedures.

3.2 Well Demobilization

Prior to departure from a well, be sure to secure the well as follows:

- Lock the well cap or well monument lid. If a lock is missing or is difficult to operate, document this on the appropriate field form(s) and notify the CH2M FTL immediately so a replacement lock can be used to lock the well.
- Secure all bolts, if present, on a well vault lid prior to departure. If there is(are) bolt(s) missing, document this on the appropriate field form(s) and notify the CH2M FTL immediately.

4.0 Key Checks and Items

- Additional weight at the end of the WL indicator may be necessary at depths deeper than 80 feet because of the buoyancy of the cable when the weight of the tape is approximately equal to or greater than the weight of the probe.
- Use caution when lowering the probe into the well; set reel on stable surface and maintain support and control of reel during use; do not let the probe tip and tape free-fall down the well (maintain relatively slow descent speed into well at all times); always hold onto the meter's reel handle and use the reel lock mechanism to hold probe in place during breaks; engage reel lock before you become too fatigued to prevent injury or strain.

All decontamination liquids generated during manual WL measuring will be containerized and handled, as outlined in the Waste Management Plan (WMP).

STANDARD OPERATING PROCEDURE

Low-Flow Purge and Groundwater Sampling

1.0 Purpose and Scope

This Standard Operating Procedure (SOP) provides a general guideline for the collection of groundwater samples using low-flow well purging techniques in cased wells or open coreholes/boreholes. These procedures may not apply at cased wells or open coreholes/boreholes that are intermittently dry; in these wells or coreholes/boreholes, consult with the CH2M field team leader (FTL) for the appropriate purging, if applicable, and sampling procedures.

Additionally, this SOP can be used in wells or coreholes/boreholes with single or dual packer(s). However, additional or different drawdown criteria may apply. The CH2M FTL, subject matter expert (SME), and/or quality manager (QM) must be consulted prior to implementing low-flow purging and sampling in packered wells/coreholes/boreholes.

2.0 Equipment and Materials

- Submersible pump with controller
- Personal protective equipment (PPE) including gloves, boots, and glasses per the Health and Safety Plan (HASP)
- Sample containers, including any necessary shipping materials
- Water level (WL) indicator
- Water quality meter with a flow through cell
- Turbidity meter or turbidity probe for water quality meter
- Decontamination equipment (bucket or pail, spray bottles of distilled water and/or detergent solution such as Alconox or Liquinox, and paper towels)
- Bucket for containing purge water with graduations indicating volume
- Stopwatch
- Plastic sheeting
- Compressed gas with regulator or oil-less air compressor for positive pressure pumps
- Graduated cylinder or measuring cup
- Hand tools for opening flush-mount wells
- Keys to open well locks
- Coolers with ice for holding samples
- Sample data sheets and labels
- Field Log Book

3.0 Procedures and Guidelines

CH2M HILL will use the low-flow sampling method when possible for collecting groundwater samples from monitoring wells or from temporary packer-isolated intervals in open boreholes. The general procedure consists of:

- Site preparation
- WL measurement
- Packer placement, if applicable
- Pump configuration
- Low-flow sample collection
- Sample preparation, collection, and handling

In the case of collecting groundwater from packer-isolated intervals of open boreholes, the packer setup, inflation, and pump configuration protocols listed in the Packer Testing SOP should be followed. The general site preparation, sample preparation and handling, low-flow sample collection, and equipment decontamination procedures described in this SOP should be followed to the extent possible.

3.1 Site Preparation

All personnel will wear PPE as specified in the HASP. A plastic ground sheet will be placed beneath sampling equipment to prevent contamination of sampling equipment by surface soils during WL measurement, well purging, sampling, or decontaminating sampling equipment. The ground sheet should be large enough and configured so that any sample water that may be spilled will remain on this sheet. All sampling equipment including, but not limited to, WL indicator, packers, pumps, tubing (if reusable), water quality meters, and field probes will be thoroughly cleaned and rinsed with distilled water prior to, between, and after any contact with water in a monitoring well.

Water quality meters will be maintained and calibrated according to manufacturer's specifications. Calibration will occur at the start of each day at a minimum and will be recorded in the field logbook along with the equipment serial number and who performed the calibration.

3.2 Water Level Measurement

Before setting packers and purging of groundwater, static WLs in the monitoring wells or coreholes/boreholes will be measured. WLs will be measured using a decontaminated, electronic WL indicator with an accuracy of +/- 0.01 foot. Static water-level measurement may not be practical for packer-isolated intervals, depending on the number of vertical sample collection intervals that will be sampled and whether a multi-port sampling system is to be installed in the borehole.

3.3 Pump Configuration vs. Water Level Measurements

A positive displacement (i.e., bladder pump) or electric submersible variable speed drive pump (ES-VFD) with Teflon-lined, high-density polyethylene (HDPE) hose/tubing or drop pipe will be used for low-flow purging and subsequent sampling. All pumps will be operated and maintained in accordance with manufacturer's recommendations. All non-dedicated pumps and reusable parts will be decontaminated between sampling of different wells using the procedures described in the Equipment Decontamination SOP.

After measuring the static WL in a well, compare it to the pump inlet depth (in all wells/coreholes/boreholes having dedicated pumps), the bottom of the well screen (in cased wells without a dedicated pump), or the total depth (TD) of the well (in open coreholes/boreholes without dedicated pumps). If the water column length above the pump inlet, the bottom of the well screen, or the TD of the well is > 3 ft, then proceed with the low-flow purging and sampling. Confirm with the CH2M FTL whether or not a well (with or without a

dedicated pump) should be purged/sampled (using the low-flow or an alternative method) if the water column is <3 feet (ft) above the:

- pump inlet (for dedicated pumps)
- bottom of the screen in cased wells
- total depth of the uncased well/corehole/borehole.

In wells without dedicated pumps, lower a decontaminated pump deeper than the minimum calculated pump depths (this information is available in field instructions [FI] for groundwater purging/sampling or from a CH2M FTL); the minimum pump depth takes into account the presence of a surface casing in open coreholes/boreholes or top of the screen interval in cased wells. Basically, the inlet pump will be set as follows:

- Cased wells with fully inundated screen interval: set the pump inlet mid-way in the screen interval.
- Cased wells with partially saturated screen interval: set the pump inlet in the saturated water column mid-way between the static WL and the bottom of the screen interval.
- The sumps in cased wells are NOT included in setting the pump inlet depth; just like the water above the top of the screen, water collected in the sump is considered to be stagnant.
- Open coreholes/boreholes: set the pump inlet midway in the saturated water column BELOW the surface casing.

In the case of a packered zone, the pump will be placed approximately in the middle of the packered interval.

3.4 Low-Flow Sample Collection

Low-flow groundwater sampling is the process of purging and sampling wells at flow rates from within the well screen (or packered) zone that minimize purging and improve sample quality. In general, the procedure consists of slowly purging the water from the well or packered interval while monitoring the field parameters for stabilization. When the change in the field parameters over time is below a specified amount, it is then appropriate to collect the sample. Monitoring well purging and sampling will generally proceed from the potentially least contaminated well to the most contaminated well, according to existing data (when practical).If the well is to be sampled for metals, it will be purged so that pumping rates will be low enough to not increase turbidity in the purge water. The amount of purged fluid will be measured by filling a graduated bucket or cylinder and using a stopwatch to note the flow rate of the pump versus elapsed time.

The proper flow rate for each well will be based on the ability to establish a low-flow rate at an acceptable level of drawdown (<0.33 foot), and with minimum fluctuations of the WL during pumping. To achieve this, the pump will be initially operated at the minimum flow capacity of the pump and the flow rate will be gradually increased until some initial drawdown is observed. The flow rate will then be reduced slightly to achieve a stabilized purge rate for the well. In packered intervals, if drawdown cannot be measured, the flow rate should be maintained such that the interval does not show signs of going dry (minimal air bubbles, ability to maintain steady discharge rate).

It should be noted whether or not the pump has a check valve. A check valve is required if the pump is shut off. **Under no circumstances should the well be pumped such that the water level reaches the pump inlet**. Always begin pumping at a lower flow rate. It is anticipated that flow rates on the order of 0.1 to 0.5 liter per minute (L/min) will be achieved. However, if no drawdown is observed, increase the flow rate until drawdown is observed and does not exceed 0.33 foot or until the maximum flowrate of the pump is reached, which can be allowed to exceed 1.0 L/min. However, flow rates will not exceed 1.0 L/min without prior approval from the CH2M FTL (who will get approval from the CH2M SME and/or QM).

The following bullets summarize what to do if drawdown exceeds 0.33 foot. This information should be noted in the field notebook or ground-water sampling log with a recommendation for a different purging and sampling procedure to be implemented the next time the well is to be sampled.

- Decrease flow rate until drawdown is less than 0.33 ft, to the minimium flow rate the pump can sustain without shutting off, or 100 mL/min, whichever is higher. If drawdown does not stabilize, even after decreasing flowrate to 100 mL/min or the minimum flow rate of the pump, then allow the drawdown to stabilize and continue purging until parameter stabilization. This can be allowed if, **and only if**, the stabilized WL remains above the **top of screen interval (in cased wells**) or **inlet of the pump (in open coreholes/boreholes)**.

- If the WL draws down to the **top of screen interval (in cased wells**) or **inlet of the pump (in open coreholes/boreholes)** during purging, shut-off pump and allow well to recover for 15 minutes. Note whether or not a check valve is present in the pump. Measure and record recovered WL.

    - If the well is recharging slowly (i.e., WL is 0.5 ft above the inlet after 15 minutes), do not turn on pump. Contact the CH2M FTL for instructions on purging and/or sampling. A possible sampling scenario is to check the water level the next day (before 24 hours of start of purging), and, if the groundwater in the well indicate 80% recovery, a sample will be collected (most likely with sample priority).

    - Otherwise, restart pump. If WL again drops down to pump inlet or top of screen again, shut off pump. Repeat one more time (this will be the third purging attempt). If 2 system volumes (see next paragraph) have been purged at the end of the third purging attempt, samples can be collected when the pump is restarted.

After purging starts, measurement of water quality parameters can begin once a system volume of water has been purged using dedicated pumps or once water reaches the ground surface using a portable pump (either bladder or ES-VFD). Typically, system volumes are included in the FIs; if this information is not available, then system volumes are calculated as follows (the volume of the flow-through cell, if used, is not included because it is assumed that the flow-through cell has been drained prior to demobing from the previous well and is empty when purging starts):

- Bladder pumps: The sum of the volumes of the bladder pump and tubing.
- ES-VFD pumps: The volume of the riser pipe (aka drop pipe) or tubing, if used. It is assumed that the pump itself contains a motor and there is no volume inside the pump for water storage.

Accurate measurement of the field parameters will require a flow-through cell or other means to ensure that the purge water is continuously monitored. Although the flow-through cell is the preferred method, some flow-through cells have a maximum allowable flow rate and exceeding this flow rate can damage the cell. For example, do not use the Horiba U-50 series flow-through cell if the flow rate exceed 500 mL/min. If a flow-through cell is not used, Acceptable alternate methods are bulleted as follows and must be documented on the appropriate field form(s):

- Filling the measuring cup provided with the Horiba water quality meter with a grab sample of the purge groundwater from the discharge line/tubing (or by-pass spigot).
- Placing the probes in a small bucket or beaker that continuously overflows, with the discharge tubing placed near the probes, and covering the beaker or bucket with clear plastic film (such as Saran Wrap).

Careful, continuous measurement of field parameters including pH, temperature, specific conductance, dissolved oxygen (DO), and oxidation-reduction potential (ORP) will be used to assess when purged water has reached equilibrium. The interval between readings will be dictated by the stabilized pumping rate for each well. Initial field parameter readings can be collected up to a maximum of 10-minute intervals. The

field parameter measurement interval will be reduced to no less than 2 minutes apart when approaching stabilization. Be sure that the frequency to record the water quality parameters takes into account the flow rate and, if a flow-through cell is used, the amount of time required to "cycle" the groundwater in the flow-through cell. An initial change in the measurements typically indicates that water is being drawn from a different source ("active" versus "stagnant" water). Stabilization of these parameters would indicate that the water is coming from a steady-state source (the formation immediately surrounding the well screen near the pump intake). Equilibrium conditions are sometimes achieved after extraction of less than 10 L, with 4 to 8 L being the average reported in published studies.

Each well or packered interval will be pumped until the measured field parameters have stabilized over three successive readings a minimum of 2 minutes apart prior to collecting samples. Stabilization criteria are:

- ± 0.1 standard unit pH
- ± 3 percent conductivity
- ± 10 millivolts (mV) ORP
- ± 0.3 milligram per liter (mg/L) DO
- ≤ 10 nephelometric turbidity units (NTU) or ± 10 percent turbidity

If parameters do not stabilize even after decreasing flowrate and 3 system volumes of groundwater have been purged or 1 hour since commencement of purging, whichever occurs first, then:

- Note that the parameters have not stabilized, record the final set of parameters, then proceed with the collection of groundwater samples.
- Notify the CH2M FTL in case these samples will need to flagged as "screening level" samples.
- If a system volume ≤ 6L, and the flow rate is 100 mL/min (60 minutes of purging will only produce 6L at this flow rate), consult with the CH2M FTL on when sampling can proceed; in this case, the purging may be allowed to continue for up to one more hour prior to sampling.

3.5 Sample Preparation, Collection, and Handling

Before collecting any groundwater, the sample containers should contain adequate and correct preservative in accordance with the guidelines in the Quality Assurance Project Plan (QAPP).

Samples to be analyzed for volatile organic compounds (VOCs) will be collected first, followed by total petroleum hydrocarbons as gasoline (TPH-GRO) and/or carbon specific isotope analysis (CSIA), to minimize the effects of volatilization caused by disturbance of the water surface in the well. When filling 40mL VOAs for VOCs, TPH-GRO, and/or CSIA, reduce flow rate to ~100-150mL/min. Once all VOAs are filled, the flow rate can be increased to the flow rate used during purging to collect the remaining samples. VOC sample containers will be filled completely to the top of the container, leaving no air space above the liquid. The cap should be screwed on securely to prevent leaking. Sample collection should proceed with remaining analyses. If filtered metals are to be collected, they should be sampled last to minimize turbidity concerns. In the event turbidity is increasing, filtered metals should be collected directly following VOCs, then proceed with remaining analyses.

If sample volume is reduced due to dewatering (i.e., unstable drawdown), refer to the FI or the CH2M FTL for sample priority. If the flow rate is around 100 mL/min and there is limited time for sampling at the end of the day, consult with the CH2M FTL for sample priority and to determine whether or not sampling should continue the next day. An example would be that anions, due to short holding time, may be collected before the end of the day rather collected the next morning. If sampling is allowed to continue the next morning and all VOC, TPH-GRO, and CSIA samples have been collected the day before, then,:

- If the pump has a check-valve, it is assumed that the water level still resides in the tubing or drop pipe. Sampling can resume once the pump starts.

- If the pump does not have a check-valve, note this in the field form and notify the CH2M FTL that the pump does not have a check valve. The well will need to be purged again using the low-flow procedures outlined above prior to sampling.

The samples should then be packed to prevent breakage and stored at approximately 4° Celsius. Transport and shipping of the samples should be conducted in accordance with the QAPP.

3.6 Well Demobilization

Prior to departure from a well, be sure to secure the well as follows:

- Lock the well cap or lid. If a lock is missing or is difficult to operate, document this on the appropriate field form(s) and notify the CH2M FTL immediately so a replacement lock can be used to lock the well.
- Secure all bolts, if present, on a well vault lid prior to departure. If there is(are) bolt(s) missing, document this on the appropriate field form(s) and notify the CH2M FTL immediately.

4.0 Key Checks and Items

- Wear proper PPE per the HASP.
- Decontaminate pump and all reusable parts prior to and between sampling.
- All purge and decontamination liquids generated during sampling will be containerized and handled as outlined in the Waste Management Plan.

STANDARD OPERATING PROCEDURE

Multiport Well Groundwater Sampling

1.0 Purpose and Scope

This Standard Operating Procedure (SOP) provides a general guideline for the collection of groundwater samples from Westbay and Flexible Liner Underground Technology (FLUTe) multiport wells. Unlike other groundwater purging and sampling methodologies, these sampling systems do not require parameter stabilization prior to sampling.

2.0 Equipment and Materials

- Water level indicator appropriate for well type
- Personal protective equipment (PPE) including gloves, footwear and other equipment per the Health and Safety Plan (HASP)
- Paper towels
- Field logbook
- Well keys, hand tools
- Sample bottles
- Drums or buckets for purged water
- Flow through cell
- Water quality meter and turbidimeter

2.1 Westbay Wells

- MOSDAX Sampler Probe
- MOSDAX Automated Groundwater Interface (MAGI)
- Hand held Controller (HHC)
- Winch with cable
- Stainless-steel cylinders with connecting tubes
- Battery source
- Counter and tripod

2.2 FLUTe Wells

- Compressed gas tank (such as nitrogen)
- Regulator and apparatus
- Extra tubing for discharge lines

3.0 Procedures and Guidelines

3.1 Westbay Wells

3.1.1 Westbay Well Configuration

Sampling is performed using a remotely controlled probe connected to one or more evacuated stainless-steel sampling cylinders. The probe is lowered to the depth of the monitoring interval to be sampled. Once the probe has been lowered to the appropriate depth of the desired sampling port, the probe's location arm is activated to allow proper positioning of the probe relative to the targeted sampling port. After the probe is seated firmly at the desired port, a mechanical foot is deployed to press and seal the probe's sampling valve against the sampling port. Water residing outside of the Westbay casing then flows into the sampling

cylinder. The probe is retrieved to the surface and the sample is transferred to the appropriate sampling containers.

3.1.2 Westbay Well Groundwater Sampling

The Westbay sampling procedures are outlined below.

Surface Checks

1. Remove the MOSDAX Sampler from its storage case. Inspect the probe housing and body for damage
2. During winter months, if the MOSDAX Sampler was shipped to the site, verify that the freezing indicator (aka, Cold Snap) inside the case containing the sampler is not red (see photos and captions below for instructions). This is check is needed due to the presence of a temperature-sensitive pressure transducer inside the sampler.

Cold Snap when sampler has not been exposed to freezing temperatures. This is how the sampler should be received.	Cold Snap when sampler has been exposed to freezing temperatures. Turn on the MOSDAX sampler and check that it is reading atmospheric pressure correctly prior to use. If it is not correctly reading atmospheric pressure at the site, notify the CH2M FTL and contact vendor that shipped the sampler.

3. Assemble the tripod and counter over the well. Run the cable over the counter.
4. Connect the probe to the cable. Before attaching, inspect the O-ring at the top of the probe for wear and lubricate if necessary. The O-ring should be clean and intact. Tighten the nut by hand only.
5. Connect the 2-pin cable from the MAGI to the cable reel. With the MAGI off, connect the 3-pin cable from the MAGI to the power supply.
6. Connect the 9-pin cable from the HHC to the MAGI and turn the MAGI on.
7. MOSDAX Sampler Checks—perform the following surface checks to ensure that the sampler and the location arm and the shoe mechanisms are operating normally:
    a. Turn on the sampler and verify that the sampler is showing the correct atmospheric pressure at the site. If not, notify the CH2M FTL and contact the vendor who shipped the sampler.
    b. Release the location arm. The location arm should extend smoothly. The number of revolutions used to release the location arm is displayed and should be 15 to 16 revolutions. If a smaller number of revolutions is reported, retract the arm and repeat.

c. Place the probe in a piece of Westbay casing or coupling.

d. Activate the shoe. The shoe should extend and hold the probe firmly in the coupling or casing. The display should indicate 16 to 19 revolutions. A reading of 23 revolutions indicates the probe is activated in open air.

e. Retract the backing shoe.

7. Check that the face plate for sampling and the plastic plunger are installed on the sampler. Once steps 1 through 7 are complete the probe is ready to be lowered down the Westbay casing.
8. Attach the stainless-steel sample cylinders. Depending on the sample volume to be collected, the sample cylinders can be connected in series; each has a volume capacity of 250 milliliters.
9. Locate the supplied vacuum coupling and attach it to the top of the Westbay casing.
10. Release the location arm. Insert the probe in the vacuum coupling until it locks into the helical groove.
11. Deploy the shoe.
12. Close the sampler valve. The motor should run for about 5 seconds. The display should indicate one revolution.
13. Use the vacuum pump to apply a vacuum through the vacuum coupling. The vacuum should remain constant. If the vacuum is not maintained, inspect for leaks at the face seal of the probe, the connection to the pump, and the probe sampling valve.
14. Once a vacuum has been maintained, open the sampler valve. Apply a vacuum again to check that connections are sealed.
15. Close the sampler valve. A vacuum has now been applied to the steel sample cylinders.
16. Retract the shoe.

Sampling

1. At the beginning of each day of sampling a well containing the Westbay sampling system, using the MOSDAX sampler, record the ambient atmospheric pressure at the top of the Westbay casing.
2. Check to make sure the head inside the Westbay casing is lower than the head outside the measurement port to be sampled; this step will ensure that water will flow in to the casing from the formation and not vice versa:

   a) Lower a water-level indicator to measure and record the water level inside the Westbay Casing. Verify that this is at least 10 feet above the shallowest port in the Westbay sampling system. Add potable water if necessary.

   b) Lower the MOSDAX sampler to the measurement port to be sampled. Do NOT open the port. Using the MOSDAX sampler, measure and record the pressure reading inside the Westbay well at the sampling port. Confirm that this pressure is greater than the head outside of the measurement port.

3. With the location arm retracted, lower the probe into the Westbay casing until it is immediately below the lowest measurement port coupling to be sampled. The Collar Detect Command function on the MAGI is used to detect the magnetic collars installed on the Westbay casing. As the MOSDAX lowers past one of the collars, a beep can be heard from the MAGI. If desired, the Collar Detect Command can be cancelled by pressing key on the HHC. NOTE: Not all measurement ports to be sampled will have a magnetic collar; in this case, use the cable counter readout and magnetic beeps of shallower ports to verify the depth of the sampler.
4. Release the location arm. The display should update and beep after the arm is released.

5. Raise the probe about 0.5 meter (1.5 feet) above this measurement port. If the probe is accidentally lifted above the next higher coupling it will be necessary to retract the location arm and lower the probe to below the measurement port and release the arm.
6. Lower the probe gently until the location arm rests in the measurement port.
7. Record the pressure reading.
8. Activate the probe and record the formation pressure.
9. Open the sampler valve. The pressure should drop and then slowly increase as the steel sample cylinders fill. When the pressure in the cylinders equals the zone pressure measured during Step 8, the cylinders are full. Wait a maximum of two minutes per sample cylinder even if the pressures are not equal.
10. Close the sampler valve and retract the shoe.
11. Record the pressure reading. A reading the same as that measured in Step 7 indicates that the sample is properly sealed and contained.
12. Reel the sampler to the surface and remove it from the Westbay casing.
13. **Do not open the sampler valve as damage to the probe or injury to the operator could occur.**
14. Remove the cap from the bottom sample cylinder and open the valve to release the pressure and to transfer the sample to the appropriate packaging containers.
15. Open the sampler valve to allow the sample to flow from the cylinders. Once the pressure in the sampler and cylinders has decreased to atmospheric, the cylinders may be disconnected to speed the process.
16. Take particular care in handling pressurized samples. It is recommended that the pressure is released from the MOSDAX sampler into a non-Volatile Organic Analysis (VOA) sample bottle (preferably TDS, anions, alkalinity). Once the groundwater inside the sampler is no longer under pressure, start filling the VOAs for volatile organic compounds (VOCs), total petroleum hydrocarbons as gasoline (TPH-GRO), and/or carbon specific isotope analysis (CSIA) analyses to minimize volatization/aeration of the samples.
17. At the end of each day of sampling, decontaminate all sampling equipment that has been in contact with groundwater. Also, be sure to store the MOSDAX sampler in a temperature-controlled location. **Do not store the sampling in a location that may be subject to freezing temperatures; this may damage the transducer inside the sampler.**

3.2 FLUTe Wells

3.2.1 FLUTe Well Configuration

The water flows from the formation into the spacer, through the port, into the tube, which lies on the inside surface of the liner. The water flows from the port via the tube to the bottom of the hole, and then upward through a steel check valve into the "U" shaped tube. The water rises in both legs of the U tube. In the larger (1/2-inch inside diameter [ID]) tube, the water level can be tagged from the surface. A gas pressure is applied from a regulated nitrogen bottle to the large tube to drive the sample water through the second check valve to the surface. After purging the tubing, the sample water does not contact the drive gas. By driving the water with a sufficient gas pressure (the “recommended purge pressure”) to drive all of the water in the pump tube and the sample tube to the surface, the water in the pump tubing is nearly all expelled. The purge stroke is complete when gas is expelled from the sample tube following the water flow.

The sampling flow is best driven on the fourth (or fifth) cycle by a “recommended sampling pressure,” which is less than that needed to drive gas through the bottom of the pump tube. The pressure recommended is that which will drive the water to near, but not out of, the bottom of the large tube. That recommended

pressure, "the sampling pressure," is calculated in the spreadsheet provided with each system from the vendor. The pressure regulator is set to the sample pressure, which is lower than the purge pressure. Opening the three-way valve will then apply the sample pressure to the system, causing flow from the sample tube. The analytical sample bottles can then be filled with groundwater, using the methods mentioned previously in this section. After the bottles are filled, a final cycle is completed at the recommended purge pressure to remove water from the sampling lines as a precaution for potential damage from freezing and to be able to measure a representative head value after the formation water naturally fills the sampling tubes.

3.2.2 FLUTe Well Groundwater Sampling

The FLUTe sampling procedures generated by the vendor (http://www.flut.com/about.htm) are summarized below:

1. Check the water levels within each port and check the water level inside the liner, and add potable water, if necessary. Record all water levels in the field logbook. Water levels should be measured according to the Manual Water Level Measurements SOP.
2. Connect the gas driver source to the gas drive tube for the port.
3. Set the regulator to the recommended purge pressure.
4. Expel the tube water at the suggested purge pressure. Record the purged water volume for verification of a good purge. Note the water flow time of the purge stroke. Repeat for each port. Note: If indicated as such on the FLUTe sampling form, all ports can be purged simultaneously.
5. Allow the tubing to refill. Repeat the purge (this will be the second stroke). Collect the purge volume to ensure that the amount removed is at least the "port tube volume." Minimum allowed recharge time between each stroke is such that allows all individual ports produce at least 75% of the volume generated by the first stroke in their respective port.
    - For a single port, if two consecutive subsequent purge strokes after the first stroke each produces ≤50% of the volume of water than in the first stroke, please contact the CH2M FTL, STC, and/or QM to discuss whether or not a purge stroke (or two) will need to or can be skipped for that port to increase the amount of time for recharge between strokes (this will ensure that there will be sufficient volume at time of sampling either for all or some of the required analyses).
6. Purge a third and fourth stroke.
    - Discuss with the CH2M FTL, STC, and/or QM if there is insufficient time to complete all strokes and collect the groundwater samples that day.
    - A possible solution (if approved by the CH2M FTL, STC, and/or QM) is to allow the ports to recharge overnight after the 4th stroke and collect the samples the next day (as long as it is <24 hours of the start of the 4th stroke).
7. Allow the tubing to refill for the sample stroke (fifth stroke).
8. Reduce the driving pressure to the "sampling pressure."
9. Reduce the pressure, if needed, to slow the flow and collect the samples and water quality parameters. Note the following:
    - Multiple strokes may be needed to fill all sample bottles for chemical analysis; this is allowed.
    - Do not collect VOC samples during the first ~250 mL (this is the minimum recommended discard volume recorded on the FLUTe Sampling Parameter form included in the field instructions and varies from port to port and well to well); this volume can instead be collected either in the Horiba cup, or

in the sample bottle for TDS, alkalinity, or anions (this will decrease the need for an additional stroke to complete the sampling). If the FLUTe Sampling Parameter form is not available, contact the CH2M FTL for a copy of this form.

- Do NOT use the Horiba U-50 series flow-through cell (it is not rated for pressures exceeding 35 psi). Instead, fill the measuring cup provided with the Horiba with a grab sample of the groundwater from the discharge tubing. Record that a flow-through cell was not used and how the water quality parameters were measured.
- Do not fill the Horiba cup at the end of a sampling stroke; this will prevent the collection of sample water with air bubbles. Allow the dissolved oxygen (DO) to stabilize prior to measuring this parameter. Note: ambient DO is 8-9 mg/L; if DO is in this range or higher, check that the Horiba cup is full.

10. Continue the final purge of the water out of the sampling line by raising the driving pressure to the purge pressure value. Repeat with each port.
11. When the sampling system has refilled, tag the water level, if desired, or the current water table. If a port system is refilling slowly, tag it at a later time.

3.3 Well Demobilization

Prior to departure from a well, be sure to secure the well as follows:

- If at a well containing the Westbay Sampling system, record the ambient atmospheric pressure at the top of the Westbay casing using the MOSDAX sampler.
- Lock the well cap or lid. If a lock is missing or is difficult to operate, document this on the appropriate field form(s) and notify the CH2M FTL immediately so a replacement lock can be used to lock the well.
- Secure all bolts, if present, on a well vault lid prior to departure. If there is(are) bolt(s) missing, document this on the appropriate field form(s) and notify the CH2M FTL immediately.

4.0 Key Checks and Items

- Wear appropriate PPE per HASP.
- Decontaminate tools between samples (Westbay system).
- Collect volatiles sample first, then semi-volatiles. Then collect the remaining analyte groups, if any remaining.
- All purge and decontamination liquids generated during sampling will be containerized and handled as outlined in the Waste Management Plan.

STANDARD OPERATING PROCEDURE

Equipment Decontamination

1.0 Purpose and Scope

The purpose and scope of this Standard Operating Procedure (SOP) is to provide general guidelines for the decontamination of sampling and monitoring equipment used in potentially contaminated environments.

2.0 Equipment and Materials

- Distilled water
- Potable water from a municipal water supply or bottled drinking water in 5-gallon containers, otherwise an analysis must be run for appropriate volatile and semivolatile organic compounds and inorganic chemicals (for example, Target Compound List and Target Analyte List chemicals)
- 2.5 percent Alconox or Liquinox detergent and water solution
- Containers or squirt bottles for detergent solution and rinse waters, scrub brushes, plastic bags, and sheets
- Phthalate-free gloves and other personal protective equipment (PPE) per the Health and Safety Plan (HASP)
- Decontamination pad and steam cleaner/high-pressure cleaner for large equipment

3.0 Procedures and Guidelines

3.1 Drilling Rigs

Before the onset of drilling, after each borehole, before drilling through permanent isolation casing, and before leaving the site, heavy equipment and machinery will be steam cleaned in an area designated by CH2M HILL or NASA. The equipment will be steam cleaned until no visible signs of dirt are observed. The steam-cleaning area will be designed to contain decontamination waste and waste water.

3.2 Downhole Drilling Tools

Downhole tools will be decontaminated using a three-stage rinse before the onset of drilling and between boreholes. This will include, but will not be limited to, rods, split-spoons or similar samplers, coring equipment, and augers. The three stage rinse consists of rinsing equipment in (1) detergent solution, (2) potable water, and (3) distilled water.

Before the use of a sampling device such as a split-spoon sampler for the collection of a soil sample for **physical characterization**, the sampler will be cleaned by scrubbing with a detergent solution followed by a potable water rinse. Before the use of a sampling device such as a split-spoon sampler for the collection of a soil sample for **chemical analysis**, the sampler shall be decontaminated per the procedures outlined in the following subsection.

3.3 Field Equipment

3.3.1 Water-level Indicators

Water-level indicators that consist of a probe that comes into contact with the groundwater must be decontaminated using the following steps:

- Wash with Alconox or Liquinox solution.
- Rinse with tap water.
- Rinse with distilled water.

3.3.2 Probes

Probes (for example, pH or specific conductivity electrodes, geophysical probes, or thermometers coming in direct contact with the sample) will be decontaminated using the procedures specified above unless manufacturer's instructions indicate otherwise. Devices have been fouled by non-aqueous phase liquid, if encountered, should be cleaned using Alconox solution. For probes that make no direct contact (for example, organic vapor monitoring equipment, such as a field photo ionization detector), the probe will be wiped with paper towels or cloth wetted with methanol.

3.3.3 Other Sampling Equipment

Other sampling equipment such as spatulas, spoons, or bowls should be decontaminated and cleaned as described below:

Reusable sampling equipment is decontaminated after each use as follows.

1. Don phthalate-free gloves.
2. Rinse and scrub with potable water.
3. Wash all equipment surfaces that contacted the potentially-contaminated soil/water with detergent solution.
4. Rinse with potable water.
5. Rinse with distilled water.
6. Air dry.
7. Completely air dry and wrap exposed areas with aluminum foil (shiny side out), plastic sheeting, or clean plastic bag (phthalate-free) for transport and handling, if equipment will not be used immediately.
8. Collect all rinsate in 5-gallon buckets; containerize and handle as outlined in the Waste Management Plan (WMP).
9. Decontamination materials (for example, plastic sheeting, tubing, etc.) that have come in contact with used decontamination fluids or sampling equipment will be disposed of as outlined in the WMP.

3.3.4 Sample Container Decontamination

The outsides of sample bottles or containers filled in the field may need to be decontaminated before being packed for shipment or handled by personnel without hand protection. The procedure is:

1. Wipe container with a paper towel dampened with Alconox solution or immerse in the solution **after the containers have been sealed**. Repeat the above steps using potable water.
2. Dispose of all used paper towels as per the WMP.

4.0 Key Checks and Items

- Clean with solutions of Alconox or Liquinox and distilled water.
- If necessary, decontaminate the outside of filled sample containers before relinquishing them to anyone.
- All decontamination liquids generated will be containerized and handled as outlined in the WMP.

The effectiveness of field cleaning procedures will be monitored by rinsing decontaminated equipment with distilled water and submitting the rinsate in standard sample containers for analysis. The frequency of collection of these samples is detailed in the Quality Assurance Project Plan (QAPP).

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STANDARD OPERATING PROCEDURE

Chain-of-Custody Procedures

1.0 Purpose and Scope

This Standard Operating Procedure (SOP) provides information on chain-of-custody (COC) procedures.

2.0 Definitions and Responsibilities

A Chain-of-Custody Record is required, without exception, for the tracking and recording of samples collected for on- or off-site analysis (chemical or geotechnical) during sampling program activities. Use of the Chain-of-Custody Record Form creates an accurate written record that can be used to trace the possession and handling of the sample from the moment of its collection through analysis. This SOP identifies the necessary custody records and describes their completion. This procedure does not take precedence over region-specific or site-specific requirements for chain of custody.

Chain-of-Custody Record Form: A Chain-of-Custody Record Form is a two- to four-part form that accompanies a sample or group of samples as custody of the sample(s) is transferred from one custodian to another custodian. One copy of the form must be retained in the project file.

Custodian: The person responsible for the custody of samples at a particular time, until custody is transferred to another person (and so documented), who then becomes custodian. A sample is under one's custody if:

- It is in one's actual possession.
- It is in one's view, after being in one's physical possession.
- It was in one's physical possession, and then he/she locked it up to prevent tampering.
- It is in a designated and identified secure area.

Sample: A sample is physical evidence collected from a facility or the environment, which is representative of conditions at the point and time that it was collected.

Field Team Leader: The field team leader is responsible for determining that chain-of-custody procedures are implemented up to and including release to the shipper or laboratory.

Sample Personnel: It is the responsibility of the field sampling personnel to initiate COC procedures and maintain custody of samples until they are relinquished to another custodian, the sample shipper, or to a common carrier.

3.0 Procedures

COC procedures, record-keeping, and documentation are an important part of the management control of samples. This includes from the time the sample is collected until it is shipped. The procedures followed facilitate correct sample labeling, tracking, and identification on the COC forms, as well as tracking, sample preparation, and sample analysis by the laboratory.

3.1 Sample Identification

When in situ measurements are made, the data are recorded directly in bound logbooks or other field data records with identifying information. Information that shall be recorded in the field logbook and soil boring log, when in situ measurements or samples for laboratory analysis are collected, includes the following:

- Field sampler(s) initials or full name(s)

- Project number
- Project sample number
- Sample location or sampling station number
- Date and time of sample collection and/or measurement
- Field observations
- Equipment used to collect samples and measurements
- Calibration data for equipment used
- Measurements and observations shall be recorded using waterproof ink

3.1.1 Sample Label

Samples other than in situ measurements are removed and transported from the sample location to a laboratory or other location for analysis. Before removal, a sample is often divided into portions, depending upon the analyses to be performed. Each portion is preserved in accordance with the sampling and analysis plan. Each sample container is identified by a sample label. Blank sample labels are provided, along with sample containers, by the analytical laboratory. The information recorded on the sample label includes:

- Sample Identification: the unique sample number identifying this sample
- Date: a six-digit number indicating the day, month, and year of sample collection (e.g., 12/21/12)
- Time: in 24-hour nomenclature, 9:10 am as 0910 or 5:22 pm as 1722
- Medium: water, soil, sediment, sludge, waste, etc.
- Sample type: grab or composite
- Preservation: type and quantity of preservation added
- Analysis: VOC/8260; SVOC/8270; PCB/8082; TPM/8015M; etc.
- Sampled by: printed initials of the sampler
- Project number and client or PO number and client
- Remarks: any pertinent additional information

3.2 Chain-of-Custody Procedures

After collection, separation, identification, and preservation, the sample is maintained under COC procedures until it is in the custody of the analytical laboratory and has been stored or disposed.

3.2.1 Field Custody Procedures

- Samples are collected as described in the site sampling and analysis plan. Precisely record the sample location and ensure that the sample number on the label matches the Chain-of-Custody Record exactly.
- The person undertaking the actual sampling in the field is responsible for the care and custody of the samples collected until they are properly transferred or dispatched.
- When photographs are taken of the sampling as part of the documentation procedure, the name of the photographer, date, time, site location, compass direction in which the view is looking, and site description are entered sequentially in the site logbook as photos are taken. Once developed, the photographic prints shall be serially numbered, corresponding to the logbook descriptions; photographs will be stored in the project files. It is good practice to identify sample locations in photographs by including an easily read sign (white board and erasable markers) with the appropriate sample/location number.
- Sample labels shall be completed for each sample, using waterproof ink.

3.2.2 Transfer of Custody and Shipment

Samples are accompanied by a Chain-of-Custody Record Form, which will be generated using VDMS. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the record. This record documents sample custody transfer from the sampler, often through

another person, to the analyst in the laboratory. The Chain-of-Custody Record is completed as detailed below.

- Enter header information (date, samplers, and project name).
- Enter sample specific information (sample number, media, sample analysis required and analytical method grab or composite, number and type of sample containers, and date/time sample was collected).
- Line out any unused portion of the COC and sign and date that portion of the form.
- Sign, date, and enter the time under “Relinquished by” entry.
- Have the person receiving the sample sign the “Received by” entry. If shipping samples by a common carrier, print the carrier to be used in this space (i.e., Federal Express).
- If a carrier is used, enter the airbill number under “Remarks,” in the bottom right corner
- Place the original (top, signed copy) of the Chain-of-Custody Record Form in a plastic zip-locked bag or other appropriate sample-shipping package. Retain the copy with field records.
- Complete other carrier-required shipping papers. The custody record is completed using waterproof ink. Any corrections are made by drawing a line through and initialing and dating the change, then entering the correct information. Erasures are not permitted. Common carriers will usually not accept responsibility for handling Chain-of-Custody Record Forms; this necessitates packing the record in the shipping container (enclosed with other documentation in a plastic zip-locked bag). As long as custody forms are sealed inside the shipping container, commercial carriers are not required to sign the custody form. The laboratory representative who accepts the incoming sample shipment signs and dates the Chain-of-Custody Record, completing the sample transfer process. It is then the laboratory’s responsibility to maintain internal logbooks and custody records throughout sample preparation and analysis.

4.0 Key Checks and Items

Once samples have been packaged and shipped, the Chain-of-Custody Record copy and airbill receipt become part of the quality assurance record.

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STANDARD OPERATING PROCEDURE

Packaging and Shipping Procedures

1.0 Purpose and Scope

This Standard Operating Procedure (SOP) provides guidelines for packaging and shipping the samples collected for the project.

2.0 Equipment and Materials

- Coolers
- Ice
- Tape: strapping tape, clear packaging tape, or duct tape
- Mailing/shipping labels
- Zip-locking plastic bags, large plastic trash bags, bubble wrap, laboratory-provided foam inserts, laboratory-provided bubble wrap bags
- Chain-of-custody (COC) seal
- Personal protective equipment (PPE) per the Health and Safety Plan (HASP)

3.0 Procedures and Guidelines

The procedures below include shipment by both the laboratory courier and third party shipper such as Federal Express or Airborne Express. Packaging and shipping procedures are described below.

3.1 Sample Packaging and Transport

3.1.1 Sample Container Preparation

- Ensure labels are secured to sample containers.
- Check container lids for tightness.
- Cover glass containers with bubble wrap to prevent breakage.

3.1.2 Shipping Cooler Preparation

- Remove all previous labels used on the sample shipping cooler.
- Seal the drain plugs with tape (outside and inside) to prevent melting ice from leaking.
- Place a cushioning layer of Styrofoam popcorn or bubble wrap at the bottom of the cooler (about 1 inch thick) to prevent breaking during shipment.
- Line the cooler with a large plastic bag.
- Double-bag all ice in zip-lock plastic bags.

3.1.3 Placing Samples in the Cooler

- Place the original COC form in a zip-lock bag; tape COC form to the inner side of the cooler lid.
- Place samples in an upright position in the cooler.

- Fill void space between samples with Styrofoam popcorn, bubble wrap, or foam.
- Place ice on top of samples and between samples.

3.1.4 Closing the Cooler

- Tape the cooler lid with strapping tape, encircling the cooler several times.
- Place custody seals on the cooler lid (typically one on the front and one on the back).

3.1.5 Transport

Once packed, transport sample coolers to the closest Federal Express facility or await courier. Any disruption in the timely transport of samples to the destination laboratory should be noted in the field book.

4.0 Key Checks and Items

- Wear proper PPE per the HASP.
- Ensure all labels are secure and all lids are on tightly.
- Verify COC is complete and is in the cooler.

STANDARD OPERATING PROCEDURE

Documentation and Records

1.0 Purpose and Scope

The purpose of this Standard Operating Procedure (SOP) is to provide methods for the documentation of records taken in the field.

2.0 Equipment and Materials

- Field logbook
- Indelible pens/markers
- Field forms/notebooks

3.0 Procedures and Guidelines

3.1 Field Logbooks

Field notes commonly are kept in bound logbooks used by surveyors and produced, for example, by Peninsular Publishing Company or Forestry Suppliers, Inc. (J.L. Darling write in the Rain No. 550, Sesco, Inc.). Pages should be water-resistant, lined, and numbered, and notes should be taken only with water-proof ink, such as that provided in Sanford Sharpie permanent markers.

All lines of all pages should be used to prevent later additions of text, which may be questioned in legal terms. Any pages not used should be marked through with a line, the author's initials, and the note "Intentionally Left Blank."

All pertinent information should be entered into the logbook, including times of starting and stopping work, activities, personnel on the work site, and equipment-calibration results and any equipment problems. The weather at the start of the day should be noted at the top of the first page for the day, and any major changes in weather should be noted at the appropriate time. Summary descriptions of soil samples and drilling cuttings can be entered in depth sequence, along with photoionization detector (PID) readings and other observations. It is helpful to include a hand-drawn diagram of well construction details and sampling locations in relation to permanent site features.

No irrelevant material, including comical statements, should be entered into the logbook.

Each page of the log book should include in the header the following information (related to the work covered on that page):

- Area of Impacted Groundwater (AIG) name (LOX, B204/ELV, Alfa/Bravo, or Coca/Delta) and Task Order Number (e.g., CH570), on top of each page in the heading
- Location ID (e.g., ND-123, HAR-10), underlined

The bottom of each page should be lined out, dated, and signed. When collecting samples (e.g., soil, groundwater, rock core, air, etc.), sample IDs should be outlined in box form along with descriptions of containers used and the EPA approved analytical method (e.g., SW8260B – and not "VOCs").

The field logbook table of contents (TOC) should be filled out to indicate the start pages of major field work types for distinct work locations. For example, the table of contents would document the start page for drilling work at a new well location, and then a separate TOC entry for the page the well development starts on.

3.2 Field Forms

Pre-printed field forms notebooks may be used in lieu of bound field logbooks but are strongly discouraged. Although they do not have the advantage of containing all pertinent information in one volume, the pre-printed forms summarize the pertinent information required for a given task, which can make note taking easier. Pre-printed forms provide information which is not recorded in sequentially-numbered, bound site or field logbooks. As an alternate method to using the pre-printed field forms, the information that they maintained may be documented in the field logbooks. General site information should also be documented on the pre-printed field forms, including:

- Area of Impacted Groundwater (AIG) name (LOX, B204/ELV, Alfa/Bravo, or Coca/Delta) and Task Order Number (e.g., CH570), on top of each page in the heading
- Location ID (e.g., ND-123, HAR-10), underlined
- Site name, personnel onsite and time and date of arrival
- Ambient weather conditions
- Documentation of field activities including decontamination, sampling, and preparation

Field forms may include:

- Soil boring logs
- Rock core logs
- Soil or groundwater sample collection forms
- Calibration logs (described in more detail below)

Calibration Logs

Calibration logs may be included in the field and are used to document the proper maintenance and calibration of field testing equipment. All equipment will be inspected and approved by the Field Team Leader before being used, and a calibration log sheet shall be maintained for each instrument used on-site and shall be kept in the notebook. The calibration log will document the following:

- Name and identifying number of the instrument
- Date calibrated
- Calibration points
- Identification of the calibrator
- Manufacturer, lot number, and expiration date of calibration standards
- Results of the calibration

3.3 Field Paperwork Filing

Field log books and field forms will be scanned and saved to the project SharePoint site (https://communities.int.ch2m.com/esbg/NASACharFieldWork/Shared Documents/Field Data). All field paperwork should be turned into the field team leader (FTL). The FTL will coordinate with the project Administrative Assistant for scanning and upload of the field paperwork to the project SharePoint site. The field work hardcopies will be kept in the CH2M HILL Thousand Oaks office by the Administrative Assistant until project closeout. The Project Manager should be consulted for direction for file archiving at the completion of the project.

Scanned field paperwork files will be named using the following convention:

[AIG]_[TO]_[ID]_[DataType]_[Date].[File Extension]

Where:

[AIG] = The AIG the file is associated with, including “LX” (LOX), “BE” (B204/ELV), “CD” (Coca/Delta), “AB” (Alfa/Bravo), or “SW” (sitewide)

[TO] = The Task Order number the file is associated with (e.g. “CH544”)

[ID] = The location ID the file is associated with (e.g. well name), if applicable

[DataType] = The form or work type the file is associated with (e.g. boring log, hydraulic packer testing, well development), with easy to identify abbreviation where practical (e.g. HydrPackTest, WellDevl)

[Date] = A six digit month/day/year format (e.g., 021915 for February 19, 2015) associated with the start date of the work documented in the file.

SharePoint check-in notes should be used for further description of the information types in each file, if needed.

Key Checks and Items

Make sure that entries for a day include, at a minimum:

- AIG and TO of related work
- Date and time of entry
- Weather conditions
- Personnel onsite, including subcontractors
- Health and Safety topics
- Objectives of the work to be performed

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Appendix B
Quality Assurance Project Plan Addendum

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APPENDIX B

NASA Sitewide Groundwater Monitoring Program Quality Assurance Project Plan Addendum

B.1 Introduction

This supplemental quality assurance project plan addendum (SQAPP) for the National Aeronautics and Space Administration (NASA) Santa Susana Field Laboratory (SSFL) Sitewide Groundwater Monitoring Program includes project-specific information that supplements the Groundwater Monitoring Quality Assurance Project Plan, Appendix B, located in the Site-Wide Water Quality Sampling and Analysis Plan (WQSAP), Santa Susana Field Laboratory, Revision 1 (Haley & Aldrich, 2010). The WQSAP (Haley & Aldrich, 2010), in conjunction with the SQAPP, provides the quality assurance/quality control (QA/QC) procedures to be followed for each analytical method required for the groundwater monitoring program.

B.2 Project Description

Field and laboratory activities will follow and comply with this SQAPP and the WQSAP (Haley & Aldrich, 2010) mentioned above. The objective of the sampling program is to collect data that are of sufficient quality to be used in the decision-making process, in accordance with the project data quality objectives.

B.3 Project Organization

The NASA SSFL team for the groundwater monitoring program has been structured with a Project Manager, Technical Lead, Field Engineer, and a Project Chemist to achieve the goals of this sampling program. Currently, Jon Freed is the Project Manager and is responsible for maintaining overall quality, consistency, health and safety, staff resources, and the financial success of the project. Peter Lawson is the Senior Technical Consultant and is responsible for technical review. Randy Dean and Derek Miller are the onsite Field Engineers. Mark Fesler is the Project Chemist and is responsible for implementing the project-specific QA activities, including those described in this SQAPP.

B.4 Sampling Procedures

The sampling activities are being conducted in accordance with the NASA Sitewide WQSAP and the associated NASA Sitewide Groundwater Monitoring Field Sampling Plan, Appendix A of the NASA Sitewide WQSAP, and consists of sampling groundwater to be analyzed for selected analytical methods. Various field sampling standard operating procedures for collecting groundwater can be found in the Field Sampling Plan (Appendix A).

B.5 General Requirements

Project work will be performed in accordance with this SQAPP, which incorporates the WQSAP (Haley & Aldrich, 2010) by reference. The following clarifications to the WQSAP are presented:

- No performance evaluation samples will be submitted to the laboratory for this project effort. Laboratories will participate in the Water Pollution Study and Hazardous Waste Study programs or equivalent programs for state certifications.
- Split samples will not be collected for this project. They are not part of the data quality objectives.

Eurofins Calscience, Inc. will be providing the analytical services for this project, and is certified under the California Environmental Laboratory Accreditation Program for the fields of testing indicated in Section B.5.1. The laboratory manager will be responsible for ensuring that their personnel have been properly trained and are qualified to perform assigned tasks.

B.5.1 Site-specific Analytical Methods

Groundwater samples will be collected for laboratory analysis from each sample location as specified in the WQSAP (Haley & Aldrich, 2010). Analytical methods will be performed in accordance with the SQAPP and the WQSAP, and will be reported as definitive data results. The following analytical methods will be performed:

- U.S. Environmental Protection Agency (EPA) 300.0, nitrate, nitrite, sulfate (anions)
- EPA 1625, n-nitrosodimethylamine
- RSK-175, methane, ethane, ethene
- SM3500-FeD, ferrous iron
- SM4500-SD, total sulfide
- SM5310B, total organic carbon
- SW6010B/6020, total and dissolved metals (Table B-1)
- SW8260B, volatile organic compounds (VOCs) (Table B-1)
- SW8260B SIM, 1,4-dioxane, 1,2,3-trichloropropane
- SW8315A, formaldehyde

B.5.2 Reporting Limits and Investigative Screening Criteria

The reporting limits (RLs) for the analytes of interest in groundwater are presented in Table B-1. The table also presents the regulatory screening levels (such as groundwater screening levels [GSLs]) for comparison in evaluating the sample results.

The RLs are consistent with either the RLs established in the WQSAP (Haley & Aldrich, 2010) or RLs established by the laboratory. In either case, the RLs are less than or equal to the regulatory screening levels, with the exception of the phthalates by SW8270C SIM. In this case, the laboratory Method Detection Limit (MDL) is below the regulatory screening levels. In addition, the RLs for certain analytes have been reduced in order to meet the regulatory screening levels. These compounds are highlighted in Table B-1.

Analytes detected in the samples collected from the site at concentrations greater than the MDL but less than the RL will be flagged “J” and reported as an estimated value. Analytes that are not detected at concentrations equal to or above the MDL will be flagged “U”.

B.5.3 Sample Volume, Container Types, and Preservation Requirements

Sample volumes, container types, and preservative requirements for the analytical methods to be performed are listed in Table B-2. Sample holding time tracking begins with the collection of the samples and continues until the analysis is complete. Required holding times for the methods are also presented in Table B-2.

B.5.4 Quality Control Sampling

The QC samples to be collected for this project consist of field duplicate samples, field blanks, trip blanks, and equipment blanks. The frequency of collection for each QC sample type will be as follows:

- Field duplicate samples will be collected at a frequency of 1 duplicate per 20 samples, per event, and will be analyzed for each method.

- Field blanks will be collected at a frequency of one blank per sampling event, and analyzed for each method.
- Equipment blanks will be collected twice per sampling event, following decontamination of nondedicated sampling equipment (that is, one each for portable low-flow bladder pump or submersible pump), and analyzed for each method. (Note: if dedicated or disposable sampling equipment is used, equipment blanks may not be collected).
- Trip blank samples will be collected and shipped at a rate of one per sample shipment, and analyzed for SW8260B VOC analysis.

B.5.5 Data Validation and Reporting

Level V electronic data verification will be performed on 100 percent of the sample data for this project in accordance with the WQSAP, Appendix B, Section 5.8.2. Data validation flags will be applied as listed in Table 7-1 of the WQSAP, Appendix B (Haley & Aldrich, 2010).

B.6 Works Cited

Haley & Aldrich. 2010. *Site-Wide Water Quality Sampling and Analysis Plan, Santa Susana Field Laboratory, Ventura County, California*. December. Revision 1.

TABLE B-1
Groundwater Reporting Limits and Screening Levels
Appendix B, NASA Sitewide Water Quality Sampling and Analysis Plan, SSFL, Ventura County, California

Method	CAS No.	Analyte	GSL (µg/L)	Reporting Limit (µg/L)
EPA 300.0	14797558	Nitrate	45,000	500
EPA 300.0	14797650	Nitrite	1,000	100
EPA 300.0	14808798	Sulfate	376,000	1000
EPA 1625	62759	n-Nitrosodimethylamine (NDMA)	0.01	0.005
RSK-175	74840	Ethane	7,500	1
RSK-175	74851	Ethene	39	1
RSK-175	74828	Methane	3,100	1
SM3500-FeD	7439896	Ferrous Iron (or Iron II)	4100	100
SM4500-SD	NA	Sulfide, total	NA	50
SM5310B	TOC	Total Organic Carbon (TOC)	NA	5000
SW6010B/6020	7440439	Cadmium, total and dissolved	0.2	1
SW6010B/6020	7439921	Lead, total and dissolved	11	1
SW6010B/6020	7439965	Manganese, dissolved	150	5
SW8260B	156592	cis-1,2-Dichloroethene	6	1
SW8260B	156605	trans-1,2-Dichloroethene	10	1
SW8260B	79016	Trichloroethene	5	1
SW8260B	75014	Vinyl chloride	0.5	0.5
SW8260B SIM	123911	1,4-Dioxane	1	1
SW8260B SIM	96184	1,2,3-Trichloropropane	0.005	0.005
SW8315A	50000	Formaldehyde	100	50

µg/L = microgram(s) per liter
CAS = Chemical Abstract Service
EPA = U.S. Environmental Protection Agency
GSL = groundwater screening level
NA = not applicable

TABLE B-2
Sample Containers, Preservation, and Holding Times
Appendix B, NASA Sitewide Water Quality Sampling and Analysis Plan, SSFL, Ventura County, California

Analyte	Method	Container and Minimum Quantity	Preservation	Holding Time
Anions (NO_2, NO_3, SO_4)	EPA 300.0	500 mL/P	Chill to 4°C (±2°C)	48 hours for Nitrite/Nitrate; 28 days for all others
NDMA	EPA 1625	2- 1L/ G-TLC	Chill to 4°C (±2°C)	7 days to extraction; 40 days to analysis
MEE	RSK-175	3- 40 mL/ G-TLC	Chill to 4°C (±2°C); pH<2 with HCL	14 days
Iron (II)	SM3500-FeD	250 mL/ amber G-TLC	Chill to 4°C (±2°C)	48 hours
Sulfide	SM4500-SD	125mL/P	Chill to 4°C (±2°C); pH>10 with NaOH; ZnAc	7 days
TOC	SM5310B	250 mL/ G-TLC	Chill to 4°C (±2°C); pH < 2 with H_2SO_4	28 days
Metals[a]	SW6010B/ 6020	250 mL/P	Chill to 4°C (±2°C); pH < 2 with HNO_3	180 days
VOCs	SW8260B	3- 40 mL/ G-TLC	Chill to 4°C (±2°C); pH<2 with HCL	14 days
1,4-Dioxane/ 1,2,3-TCP	SW8260B SIM	3- 40 mL/ G-TLC	Chill to 4°C (±2°C); pH<2 with HCL	14 days
Formaldehyde	SW8315A	500 mL/P	Chill to 4°C (±2°C)	3 days to extraction/derivatization; 3 days to analysis

[a] If samples will be filtered in the laboratory (instead of field filtered), unpreserved bottles will be used. Laboratory will filter sample upon receipt and preserved the HNO3 after filtration
°C = degree(s) Celsius
DRO = diesel range organics
EPA = U.S. Environmental Protection Agency
GRO = gasoline range organics
G-TLC = glass with teflon-lined cap
H_2SO_4 = sulfuric acid
HNO_3 = nitric acid
HCL = hydrochloric acid
MEE = methane, ethane, ethene
mL = milliliter(s)
NaOH = sodium hydroxide
NDMA = n-nitrosodimethylamine
P = polyethylene
SIM = selected ion monitoring
TCP = trichloropropane
TOC = total organic carbon
VOC = volatile organic compounds
ZnAc = zinc acetate

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